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TRANSACTIONS

OF

THE FEDERATED INSTITUTION

OF

MINING ENGINEERS.

VOL. IV.—1892-1893.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

PRINTED BY ANDREW REID, SONS & CO., NEWCASTLE-UPON-TYNE.
1893.

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TRANSACTIONS

OF THE

FEDERATED INSTITUTION

OF

MINING ENGINEERS.

FEDERATED INSTITUTON OF MINING ENGINEERS.

ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE FIRST SHROPSHIRE AND STAFFORDSHIRE ARTILLERY VOLUNTEERS, SHELTON, NORTH STAFFORDSHIRE, SEPTEMBER 7TH, 1892.

MR. T. W. EMBLETON, RETIRING PRESIDENT, IN THE CHAIR.

ELECTION OF OFFICERS.

The SECRETARY announced the following elections by the Council:—

PRESIDENT.

G. LEWIS, Esq., Albert Street, Derby.

VICE-PRESIDENTS.

W. ARMSTRONG, Jun., Esq., Wingate, Co. Durham.
W. COCHRANE, Esq., Grainger Street West, Newcastle-upon-Tyne.
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TREASURER.

REGINALD GUTHRIE, Esq., Neville Hall, Newcastle-upon-Tyne.

AUDITOR.

J. G. BENSON, Esq., 12 Grey Street, Newcastle-upon-Tyne.

Mr. T. W. EMBLETON then vacated the chair, which was taken by Mr. G. Lewis.

The PRESIDENT said the honour had come upon him by surprise. However, he could only say that, so far as he was able, he hoped to further the interests of the Federated Institution of Mining Engineers. He felt considerable diffidence in following such a man as they had had as President for the last two years. However, he would do the best he could, and he trusted that at the end of the year he would be found to have fulfilled to some extent the obligations imposed upon him. He had, however, great pleasure in moving a hearty vote of thanks to the Past-President (Mr. T. W. Embleton), who had been most attentive to his duties; he had accomplished all that could be desired of him, and was well known and beloved by all who had come in contact with him.

Mr. W. COCHRANE (Newcastle-upon-Tyne), in seconding the proposition, said that the success of their meetings during the two years Mr. Embleton had been their President was due almost entirely to his personal character and the great devotion he had shown to their interests. Neither fatigue nor trouble had deterred him; he had been such a moving spirit and had given such an impetus to the Institution that it could not help prospering on the lines on which he had so ably guided it. He hoped that health would be long spared to him, and that he would see the results of his great work for the Institution.

The resolution was carried with acclamation.

Mr. T. W. EMBLETON, in acknowledging the vote of thanks, disclaimed any more credit than having quietly occupied the position of President, and trusted that he should be able to go on a few years longer doing something for the Federated Institution.

The SECRETARY read the annual report of the Council for the past year, as follows:—

THE THIRD ANNUAL REPORT OF THE COUNCIL.

The Council are pleased to congratulate the members upon the continued success that has attended the Federated Institution of Mining Engineers.

During the course of the year the North Staffordshire Institute of Mining and Mechanical Engineers applied to the Council and were, after due enquiries, admitted, and the Institution now embraces five societies,

viz.:—the Chesterfield and Midland Counties Institution of Engineers; the Midland Institute of Mining, Civil, and Mechanical Engineers; the North of England Institute of Mining and Mechanical Engineers; the North Staffordshire Institute of Mining and Mechanical Engineers; and the South Staffordshire and East Worcestershire Institute of Mining Engineers.

The Council are using every endeavour to extend their bounds, so that the Institution may embrace all interested in mining and mechanical engineering, metallurgy, and the allied industries. The influence of the Institution would be by this means rendered more effective, and the value of its Transactions greatly enhanced.

The number of members on the register since the formation of the Institution are:—

1889–90	1,189
1890–91	1,187
1891–92	1,415

The number of non-federated being:—

1889–90	50
1890–91	9
1891–92	19

General meetings have been held during the past year at Birmingham, Manchester, and London, and the papers communicated at these meetings must have enhanced the knowledge of the members upon the various questions. The thanks of the Institution are especially due to those gentlemen who have kindly allowed the members to visit their collieries and works during the course of the meetings.

A small party of members visited the successful sinking by the Poëtsch system at the Lens Collieries, and other collieries in the North of France: they were very hospitably entertained during their stay.

Presidential addresses have been given during the year to the members of the Chesterfield and Midland Counties Institution of Engineers, by Mr. Henry Lewis; the North of England Institute of Mining and Mechanical Engineers, by Mr. J. B. Simpson; the North Staffordshire Institute of Mining and Mechanical Engineers, by Mr. W. Heath; and the South Staffordshire and East Worcestershire Institute of Mining Engineers, by Mr. W. F. Clark.

The members may be congratulated upon the varied scope of the papers communicated to the Federated Institutes, and the Council trust that members will continue to send in their contributions as liberally as heretofore.

There have been several interesting contributions upon the question of mine haulage:—

"Endless-rope Haulage at the Thorncliffe, Rockingham, and Tankersley Collieries." By Mr. W. Hoole Chambers.

"Underground Haulage at the West Riding Collieries, Normanton." By Mr. W. E. Garforth.

"A Short Description of the Underground System of Haulage at Mitchell Main Colliery." By Mr. T. W. H. Mitchell.

"An Underground System of Haulage." By Mr. John Nevin.

"Underground Haulage by Endless-rope at Ansley Hall Colliery." By Mr. W. G. Phillips.

The following papers were read on questions of mechanical engineering, etc.:—

"The Meldrum Self-contained Dust-fuel Furnace." By Mr. W. Boby.

"The Pumping Appliances used in the Sinking Operations at the Cadeby New Winning." By Mr. Wm. Hy. Chambers.

"Winding by Water-balance, at Ynis Merthyr Colliery." By Mr. M. W. Davies.

"Description of a Method of Removing Deposits from the inside of Rising Main Pipes in Shafts." By Mr. R. T. Swallow.

"The Chandler Forced Draught Fan and High Speed Engines." By Mr. S. H. Terry.

"Notes on the Working of the Priestman Oil Engine." By Mr. W. H. Wain.

"Steam Engines." By Mr. John Watts.

The practical applications of electricity to mining operations have been referred to in the following papers:—

"The Practical Transmission of Power by Electricity and its Application to Mining Operations." By Mr. D. Selby Bigge.

"A Safety Appliance for Preventing Risk of Explosions in Mines, consequent on Injury to Cables conveying Electric Currents." By Mr. R. J. Charleton.

"Notes upon a Small Electric Pumping Plant." By Mr. M. Deacon.

"The Electric Transmission of Power and its Analogies in Hydraulics." By Prof. W. Garnett.

"One Use for the Telephone." By Mr. F. S. Marsh.

"Notes on an Electric Transmission Plant at East Howle Colliery." By Mr. H. Palmer.

"Electric Haulage at the West Cannock Colliery." By Mr. W. Wardle.

"Electric Haulage at the Cannock and Rugeley Collieries." By Mr. R. S. Williamson.

The use of explosives in mines has been discussed in the following papers:—

"The Report of the Austrian Fire-damp Commission." By Mr. W. N. Atkinson.

"Experiments with Explosives." By Mr. L. W. Chicken.

"The Detonation of High Explosives by Percussion." By Mr. W. J. Orsman.

"Notes on the Products and Temperature of Detonation of some High Explosives." By. Mr. W. J. Orsman.

"The Speakman Water-cartridge." By Mr. J. J. Speakman.

"An Enquiry into the Cause of the two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884." By Mr. T. H. M. Stratton.

"The Phenomena of Coal-dust Explosions." By Prof. T. E. Thorpe.

The papers relating to mine ventilation comprise :—

"The König Differential Water-gauge." By Mr. M. Walton Brown.

"The Lee Alarm Water-gauge." By Mr. M. Walton Brown.

"The Rateau Ventilator." By Mr. M. Walton Brown.

"Notes on Fan Gauges in connexion with Fan testing, and the adaptation of Fans to Mines; and Comparison of Fan and Furnace at Silverhill Colliery." By the Rev. G. M. Capell.

"The Chandler Fan." By Mr. R. S. Williamson.

The geological papers have been :—

"Mining in New Zealand.—Part I., Gold-mining." By Mr. G. J. Binns.

"The Nord and Pas-de-Calais Coal-field." By Mr. M. Walton Brown.

"A General Description of the South Staffordshire Coal-field, south of the Bentley Fault, and the Methods of Working the Ten-yard or Thick Coal." By Messrs. W. F. Clark and H. W. Hughes.

"Observations on Petroleum in Eastern Europe, and the Method of Drilling for it." By Mr. A. W. Eastlake.

"Notes on the Occurrence of Manganese Ore near the Arenigs, Merionethshire." By Mr. E. Halse.

"Notes on the Occurrence of Manganese Ore near Mulegé, Baja California, Mexico." By Mr. E. Halse.

"Notes on the Natal Coal-fields." By Mr. J. P. Hamilton.

"Witwatersrand Gold-field, Transvaal, South Africa." By Mr. J. P. Hamilton.

"The Coal-fields of Malaysia." By Messrs. J. A. Hooze, R. A. Eekout, and R. A. Van Sandick.

"Notes upon the Mines in the Argentine Republic, South America." By Mr. H. D. Hoskold.

"The Iron Ores of Spain." By Mr. J. D. Kendall.

"The Coal and Mineral Resources of Peru." By Mr. E. Lane.

"Sketch of the Geology of the Birmingham District." By Prof. C. Lapworth.

"The Witwatersrandt Gold-field." By Mr. J. M. Liddell.

"Geology of the Coal-field of Northumberland and Durham." By Mr. C. J. Murton.

"The Hæmatite Ores of Cumberland." By Mr. J. L. Shaw.

"The Northern Part of the South Staffordshire Coal-field. By Mr. A. Sopwith.

"The Tees Salt Industry." By Mr. T. W. Stuart.

Other contributions have been as follows :—

"Notes on the Gases enclosed in Coal and Coal-dust." By Prof. P. Phillips Bedson and Mr. W. McConnell.

"On Lightning in New Zealand Mines." By Mr. G. J. Binns.

"Barometer, Thermometer, etc., Readings for the year 1891." By Mr. M. Walton Brown.

"The Bethune Collieries." By Mr. M. Walton Brown.

"The Lens Collieries." By Mr. M. Walton Brown.

"The Liévin Collieries." By Mr. M. Walton Brown.
"The Nœux Collieries." By Mr. M. Walton Brown.
"The Roberts' Shot-firing Lamp." By Mr. M. Walton Brown.
"Memoir of Theophilus Wood Bunning." By Mr. C. Z. Bunning.
"Notes on Alfreton Colliery." By Mr. M. Deacon.
"The Rate of Explosions in Gases." By Prof. H. B. Dixon.
"Notes upon Redemption of Capital Invested in Collieries." By Mr. H. D. Hoskold.
"Colliery Assessments and the Rating of Mining Machinery." By Mr. G. Humphreys-Davies.
"The Causes of Spontaneous Combustion of Coal, and Prevention of Explosions on Shipboard." By Mr. M. V. Jones.
"Memoir of John Marley" By Mr. J. W. Marley.
"Memoir of Robert Miller."
"The Ordnance Maps." By Prof. J. H. Merivale.
"Notes on Various Types of Coke-ovens." By Mr. T. W. H. Mitchell.
"On an Instance of Stopping Back Water by Brick Dams." By Mr. John Nevin.
"Chemical Means of Preserving Wood and Timbers for use in connexion with Mines." By Mr. Joseph Taylor.
"The Common Definitions of Coal." By Mr. Joseph Taylor.
"The Thorneburry Safety-lamp." By Mr. E. B. Wain.
"A Safety-cage for Mines and Hoists." By Mr. John Whitelaw.
"Gold-milling." By Mr. W. F. Wilkinson.
"Coal: Its Varieties and Application to Manufactures and the Arts." By Mr. R. H. Wynne.

The foregoing list of 79 papers clearly shows the benefits received by the members, benefits which could not be obtained prior to the formation of the Institution, except at the cost of subscriptions to each of the Federated Institutes.

The desirability of establishing a Mining Institution to which the existing local mining institutes should be federated was suggested by the late Mr. T. W. Bunning in 1887; and after meetings of the parties interested, the Federated Institution of Mining Engineers came into existence on July 1st, 1889.

The first three volumes of the Transactions, now almost completed, contain papers upon nearly every question of interest to the engineer. One of the most valuable being "An Investigation as to Whether the Fumes produced from the Use of Roburite and Tonite in Coal-mines are Injurious to Health."

Another feature of the yearly volumes of the Transactions, which renders them most valuable to engineers, is the "Notes of Papers on the Working of Mines, Metallurgy, etc., from the Transactions of Foreign Societies and Foreign Publications."

LIST OF BOOKS, ETC., IN LIBRARY.

Album (Photo), No. 1.

Bathgate, Alex., Picturesque Dunedin, or Dunedin and its Neighbourhood in 1890.

Bewick, T. J., Our Home Metalliferous Mining Industries: Can they be Revived and Developed, and How?

Birmingham and Surrounding Districts, the Heart of Industrial England.

Blackburn, A. H., and Stevens, James, The Engineering Telegraph Code for the use of Engineers, etc.

Chemical Society, Journal, No. 354.

Colliery Engineer, vol. xi., Nos. 9-12; vol. xii., Nos. 1-7 and 9-12; vol. xiii., No. 1-3.

Collins, J. H., On the Origin and Development of Ore Deposits in the West of England. Parts 1 and 2.

Cory Brothers & Co., Ltd., British Coal Trade and Freight Circular for the Months ending May 31st, June 30th, July 31st, Aug. 31st, and Sept. 30th, 1892.

Cuvelier, Eug., Fermetures de Sûretè pour Lampes de Mineurs.

Engineering and Mining Journal, vol. liv., No. 14.

Howley, J. P., Geological Survey of Newfoundland, Report, 1891.

Institution of Civil Engineers, List of Members, 1891.

Llan Colliery Explosion, Verdict of the Jury. (Reprinted from the *Western Mail*, December 23rd, 1875.)

Mather, Wm., M.P., An Open Letter to, on the subject of his Proposal for Regulating the Working Hours of Miners.

Mineral Statistics of the United Kingdom, 1891.

Mines, 1891, List of Abandoned.

Mines, 1891, Summaries of the Statistical portion of the Reports of H.M. Inspectors.

Mountain, W. C., Electrical Engineering, with special reference to Electric Lighting.

New South Wales, 1885-86, Royal Commission on Collieries. Report on the Accident at Ferndale; Report on the condition of the Collieries adjacent to Ferndale; Report on the Accidents at Lithgow Valley Colliery; Report on the Bulli Colliery Accident, 1887.

Ransome, J. S., Capital at Bay.

Redwood, Boverton, The Galician Petroleum and Ozokerite Industries.

Robinson Gold Mining Co., Ltd., Witwatersrand, Transvaal, Z.A.R., Fourth Annual Report and Accounts, for the year ended 31st December, 1891.

Salt and Salt Mining.

Shone, Isaac, The Main Drainage of the Houses of Parliament, Westminster, on the Shone Hydro-Pneumatic System; enlarged edition, 1887.

Shone & Ault, The Rangoon Sewerage and Water Supply Works on the Shone Hydro-Pneumatic System, 1892.

South African Mining Journal, vol. i., No. 4.

South Staffordshire and East Worcestershire Institute of Mining Engineers, Transactions, vol. xvi.

St. Pancras Electric Lighting, Regent's Park Station.

Witwatersrand Mining and Metallurgical Review, Nos. 3-8 and 10-21.

Dr. THE TREASURER IN ACCOUNT WITH THE

FOR THE YEAR

		£ s. d.	£ s. d.
To Balance at Bank		951 8 3	
Less due to Treasurer		3 3 7	
			948 4 8
To Subscriptions for year ending July 31, 1890—			
Non-Federated—			
South Staffordshire and East Worcestershire Institute of Mining Engineers		25 0 0	
			25 0 0
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Midland Institute of Mining, Civil, and Mechanical Engineers		26 8 2	
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Federated Institution of Mining Engineers		4 18 10	
			117 13 5
To Sales of Transactions		... ...	35 5 10
			£2,082 8 7

FEDERATED INSTITUTION OF MINING ENGINEERS. **Cr.**
ENDING JULY 31, 1892.

		£ s. d.	£ s. d.
By Printing (A. Reid, Sons & Co.)—			
Transactions, Vol. II., printing	£202 17 6		
" " II., plates	111 5 0		
		314 2 6	
" " III., printing	143 15 3		
" " III., plates	102 11 8		
		246 6 11	
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A. Reid, Sons & Co	27 15 0		
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A. Reid, Sons & Co., Transactions	91 18 1		
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		132 6 1	
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Reporting	7 6 0		
A. Reid, Sons & Co., Diagrams	0 16 0		
E. Stanford, Map	7 10 0		
Use of Rooms, etc.	22 17 0		
		38 9 0	
" Incidental Expenses	... ...	13 14 0	
" Salaries, Wages, etc.—			
Accountant	1 1 0		
Secretary	250 0 0		
Treasurer	26 5 0		
Clerks, etc.	126 18 2		
		404 4 2	
" Travelling Expenses—			
Treasurer	12 0 0		
Secretary	49 1 10		
		61 1 10	
			711 18 4
" Prizes, Vols. I. and II.	... ...	... ...	5 0 0
" Balance at Bank	... ...	575 10 9	
" " in Treasurer's hands	... ...	35 0 10	
			610 11 7
			£2,082 8 7

FEDERATED INSTITUTION OF MINING ENGINEERS.—GENERAL STATEMENT, JULY 31, 1892.

Liabilities.

	£	s.	d.	£	s.	d.
Balance of Salaries	29	15	0			
Printing, etc.	500	0	0			
Reporting	16	5	6			
Prizes, Vols. I. and II.	25	0	0			
				571	0	6
Balance of Assets over Liabilities				495	11	11
				£1,066	12	5

I have examined the above Balance Sheet with the books and vouchers relating thereto, and certify that in my opinion it presents a correct view of the affairs of the Institution.

JOHN G. BENSON, Chartered Accountant.

Newcastle-upon-Tyne, September 3rd, 1892.

Assets.

		£	s.	d.	£	s.	d.
Balance at Bank		575	10	9			
„ in Treasurer's hands		35	0	10			
					610	11	7
Transactions—							
5,007 Parts, at 1s.		250	7	0			
902 Copies, Excerpts of Papers, at 6d. ...		22	11	0			
					272	18	0
Outstanding Subscriptions—							
Year ending July 31, 1891—							
Federated—							
South Staffordshire and East Worcestershire Institute of Mining Engineers		2	2	5			
Year ending July 31, 1892—							
Federated—							
Chesterfield and Midland Counties Institution of Engineers	£12 0 0						
Midland Institute of Mining, Civil, and Mechanical Engineers ...	0 15 0						
North of England Institute of Mining and Mechanical Engineers...	27 0 0						
North Staffordshire Institute of Mining and Mechanical Engineers	63 5 5						
South Staffordshire and East Worcestershire Institute of Mining Engineers...	78 0 0						
		181	0	5			
					183	2	10
					£1,066	12	5

PRIZES.

The SECRETARY announced that the Council had awarded prizes of books to the writers of the following papers printed in the Transactions :—

VOLUME I.

"The Economical Working of Steam Boilers at Collieries." By Messrs. William Armstrong, Jun., and W. J. Bird.

"Improved Coal-screening and Cleaning." By Messrs. T. E. Forster and H. Ayton.

"Winding, Banking-out, and Screening Plant at East Hetton Colliery." By Mr. Simon Tate.

"Coal-getting by Machinery." By Mr. G. Blake Walker.

VOLUME II.

"Experiments on Explosives used in Mines." By Mr. M. Walton Brown.

"Experiments with Carbonite." By Messrs. M. Walton Brown and William Foggin.

"Notes on the Coal-fields of New South Wales." By Mr. G. Blake Walker.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, EDINBURGH, 1892.

The report of Mr. M. H. Mills, the delegate of this Institution, was read as follows :—

MANSFIELD WOODHOUSE, MANSFIELD,
AUGUST 31ST, 1892.

TO THE PRESIDENT AND COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS.

DEAR SIRS,—I attended the meeting of the British Association Delegates, but nothing of any importance except Natural History subjects was discussed. More information might be obtained as to the temperature and flow of underground waters, and I suggest that our members be asked to make observations and obtain information on these subjects.

Yours faithfully,
M. H. MILLS.

Mr. HENRY T. CROOK read the following paper on "The Ordnance Maps: the Defects and their Remedies":—

THE ORDNANCE MAPS: THE DEFECTS AND THEIR REMEDIES.

By HENRY T. CROOK, C.E.

"The Ordnance Survey of the United Kingdom is one of the most remarkable and complete works of the kind that has ever been undertaken; and it will always be regarded as one of the most valuable acts of practical government that has been carried out in this country."*

At the Paris Exhibition of 1867, French experts classed the Ordnance Survey "as a work without precedent, and one which ought to serve as a model for all civilized nations."

More than a century ago the work of making a general topographical map of the United Kingdom was commenced. It was the original enterprise for which the Ordnance Survey Department was constituted—to-day that work is still unfinished. This fact alone is a sufficient corrective of the indiscriminate eulogy which has always been lavished on their own work by the responsible officials. The high encomium of the French critics is frequently quoted by them, but without mentioning that the opinion was expressed on a collection of carefully selected specimens. A later French critic has rightly said:—"This eulogium is merited in a large measure, but not without some limitations."† It is these limitations, or, to put it plainly, these defects, to which it is proposed to draw attention in this paper, and to discuss their causes and remedies.

The present state of the Ordnance Survey cannot be said to be satisfactory. Having regard to the very large outlay of public money which has been, and still is being, incurred, the results are disappointing, and far from realizing the anticipations of those who advocated the development of the original undertaking into the present broad and comprehensive scheme. The sales of maps do not increase in anything like proportion to the area of country of which maps on various scales are published. A very large proportion of the maps are obsolete—sometimes before publication, as in the case of the new 1 inch maps of the south-eastern counties.

* Sir C. W. Wilson, in his paper read before the Society of Arts, in February, 1891.

† Général Derrécagaix, *Des Cartes Topographiques Européennées*, Paris, 1891.

Notwithstanding the adoption of new processes vaunted to effect much saving in time and cost, the actual cost of production does not seem to diminish, whilst the sale price of the maps has been increased.

Many causes have contributed to bring about this unsatisfactory condition of things, but the main cause is that the whole question of the national surveys, the purposes which they should subserve, the department or departments which should be responsible for them, and the manner in which they should be carried out, has never been thoroughly considered. True, there have been many Committees of Enquiry, but no one of these has ever been entrusted with the full examination and consideration of the question in all its bearings. The Royal Commission of 1857–8 had the widest "reference;" but even that reference did not include the system of management and responsibility, the maintenance of the survey when made, or the mode of publication and sale. The reference to the present committee is also, unfortunately, limited, and precludes the full consideration of many matters which have a most important bearing on the work of the survey and the results of its operations.

The scheme of work of the Ordnance Survey is very comprehensive, and the establishment is probably the largest and most expensive maintained by any country. The French critic already cited, General Derrécagaix, expresses his astonishment at its enormous size, and the large sum of money which it dispenses. There are, however, essential differences between the British and foreign institutions having charge of the State surveys, into the details of which it is not necessary to go for the present purpose. The chief point is that the cadastral surveys in other countries are generally undertaken by a distinct department from the topographical, and they are not, as a rule, published; those who want them have to pay considerable fees for copies. Thus, though most of the European governments have more or less complete cadastral surveys, the whole cost of the work is not seen as it is in this country, where the whole of the surveys are under the control of one department, and the cadastral maps are printed and published. On the Continent also the cadastre has often preceded the general triangulation, instead of being based upon it, as ours has been.

Since 1854 the cadastral map, on the scale of 25·344 inches to a mile, ($\frac{1}{2500}$) has been made the parent map, all others being obtained from it by various processes of reduction. It is more than doubtful whether this policy has not been carried too far, and whether it does not account for the fact that we do not yet possess a topographical map of the United Kingdom.

It is obvious that no one scale can subserve all purposes. This was not generally understood at the time of "the battle of the scales," or that celebrated conflict would not have been prolonged for eleven years. It was in fact a contest between the many interests which cartography can serve, each contending for the particular scale most suitable to its special purposes. The result was very much that of the Caucus race in Wonderland, namely, that everybody won and all had prizes, but the prizes were not altogether satisfactory.

The general lines upon which the work of the survey has been conducted were laid down in the Report of the Royal Commission of 1858.

The commissioners recommended:—(1) That the 1 inch map of the United Kingdom be forthwith completed, engraved, and published; (2) that the survey of the northern counties of England and of the counties of Scotland proceed contemporaneously, and be completed and published, the cultivated districts on the $\frac{1}{2500}$ scale, and the whole on the 6 inches and 1 inch scales, except the Highlands of Scotland, which are to be surveyed on the 1 inch scale only; and (3) that the revision of the 6 inches plans of Ireland be completed.

The Select Committee of 1861-2 recommended that the 25 inches and 6 inches surveys be extended to those portions of the United Kingdom which had previously only been surveyed on the scale of 1 inch to the mile.

Since 1862, until the appointment of the present committee, the department has been left to itself, except for the occasional and generally injurious intervention of the Treasury.

On the scales of the maps it is not necessary to say much. So far at least as the cadastral and 6 inches maps are concerned the question is settled. We may regret that the scale of the latter is not a regular proportion of the former, but the 6 inches map being finished it is practically impossible to change the scale; the cost would be altogether out of proportion to the advantages to be gained.

The town plans ($\frac{1}{500}$) do not specially concern the mining engineer, but it is impossible to leave them altogether out of consideration, for they form an important and costly part of the work of the survey, and it will be necessary to refer to them in connexion with the vital question of revision.

By engineers of all kinds the 25 inches map is largely used as a basis for working-plans. It would no doubt in some cases be convenient if some of the detail were omitted, but this is scarcely practicable because it would entail another edition. The 25 inches survey in Great Britain will, when completed, consist of more than 70,000 different sheets, and

there are at least 12,000 sheets of town plans. The difficulty therefore of preparing, printing, and keeping in stock more than one edition of the cadastral survey will readily be perceived. The best policy is to put on the cadastral maps all possible information which is of value to any considerable class of users. If maps are required for special uses with only a limited or particular kind of information they can be made by tracing, leaving out the superfluous detail. It is obviously impracticable to have special editions to suit the exigencies of every professional or trade use to which maps can be put.

This argument also applies to the colouring of these large-scale maps. The colouring of the buildings greatly improves the appearance when nothing of importance is to be added, but when the maps are used as the basis of engineering schemes or works the colour interferes with the addition of the further information or design, which is usually done in red. The colouring which is done by hand also adds enormously to the cost, the additional charge varying between 1s. 6d. and 20s. per sheet according to the amount of work entailed. The simplest and most generally satisfactory method is that the houses and other buildings be distinguished from small enclosures by a light cross-hatching.

In the 6 inches map the changes in the methods of production have caused much difference in the appearance of the sheets which compose it. The engraved, the zincograph, and the photo-zincograph do not harmonize when in juxtaposition. The necessary or unavoidable differences due to this cause have, however, been enormously aggravated and intensified by several entirely needless changes which the Ordnance Department have introduced in pursuit of a policy of pettifogging economy. The most striking of these unnecessary alterations are the changes in the mode of indicating contour-lines, in the representation of buildings, and the selection of paper for printing. The draughtsmanship is also of late much inferior, especially where rough or broken ground has to be indicated. The 6 inches map of the Great Orme's Head, Caernarvonshire, Sheet 1, S.E., is a conspicuous instance.

The use of the 6 inches map is for administrative, engineering, geological, and general scientific purposes, where the representation of the forms of ground is a consideration of the greatest importance. Unfortunately, owing to the extremely shortsighted views taken by some of the committees, ably seconded by the department, the greater portion of the map has been stripped of what was its most valuable characteristic. The loss in the utility of the work through this policy is probably much greater than the money which has been saved by the reduction in the number of contours.

In the production of this map for the future the standard which the survey should endeavour to approach is that of fifty years ago, as exemplified in the 6 inches sheets of Lancashire and Yorkshire. The contouring at 25 feet vertical intervals, as on these maps, should be renewed forthwith. The savings stated to have been effected by the adoption of cheaper processes would cover the cost of the work. Sir Henry James said that the introduction of photography for the reduction of the cadastral map had effected a saving in his time of £35,000. The present Director-General states that the more recent change to photo-zincography from engraving has effected a further saving of £80,000 to £100,000. We have therefore a sum of about £120,000, which has been saved out of the original estimate for the 6 inches map; this ought to be sufficient to cover the cost of completing the contouring, at least in Great Britain. The users of the 6 inches maps having to put up with an inferior yet higher priced article in consequence of the adoption of the more economical methods of production, may justly demand that the money so saved shall be devoted to the improvement of the map by the restoration of the 25 feet contours. The greater part of the more expensive instrumental contours have been completed. As only one kind of contour, the instrumental, is now put upon the maps, it may be as well to recall the fact that on the maps of Lancashire and Yorkshire and the counties in Scotland, which were first surveyed on the 6 inches scale, there are two classes of contour-lines, the instrumental and the interpolated, the nature of the contour being indicated on the map by a difference in the character of the line. Instrumental contours are given at 25, 50, 100, 150, 200, 250, 300, 350, 400, 500, 600, 800, 1,000, 1,200, 1,400 (in some districts), and 1,600 feet; the others are interpolated contours, and not absolutely accurate. Now by a piece of almost inconceivable stupidity the character of the interpolated contour has been adopted for the instrumental contour on the more recent maps; therefore when the 25 feet contours are restored the contouring on the whole of the maps issued during the last thirty years must be redrawn.

It is strongly advocated by some that the contour-lines should be in colour as on some of the Swiss and French maps, and that some stump shading should be added to throw up the ground forms. For many purposes it is very desirable to have the relief of the ground more clearly distinguished, but on the other hand for other uses, especially geological, colour would be a disadvantage. It is questionable whether there would be sufficient sale to justify two editions, one in black and the other in colours and shaded.

The selection of rational meridians for the 6 inches and 25 inches maps is a reform which is urgently required and should be no longer delayed. The present system is quite indefensible. When the 6 inches map was commenced fifty years ago, it was for some unaccountable reason made a county map, the sheets of each county being arranged to a distinct meridian, except in the case of counties lying nearly due north and south of one another. Thus it frequently happens that large areas of counties near the boundaries are plotted to meridians much farther removed than the meridian of the bordering county.

It has frequently been pointed out that it is impossible to make a map of any large area from the old tithe maps, because each parish having been surveyed independently the maps of one will not fit together with those of the next, but exactly the same difficulty occurs with the Ordnance maps.

The parish map ($\frac{1}{2500}$) is adjusted to the meridian of the county in which it lies, so that we have in some cases the ridiculous result that adjoining parishes lying immediately north and south of one another, but in different counties are on different meridians. The height of absurdity is perhaps reached in Stirlingshire, where some parishes in the western portion of the county are adjusted to the Stirlingshire meridian, although the Dumbartonshire meridian passes through them. That is, being situated on one of the Ordnance Survey meridians the plans are actually constructed to another more than 20 miles away to the east.

In the cases of all counties now being surveyed or re-surveyed on the 25 inches and 6 inches scales, every effort should be made to correct the awkward results of this gigantic blunder. A certain number of meridians, say one at each degree of longitude, should be adopted and the map adjusted to these meridians for the distance of half a degree east and west of each, irrespective of administrative boundaries.

Filling up the border sheets of the 6 inches map by transfer from the contiguous county, though an obvious improvement, does little to obviate the difficulties created by the irrational selection of meridians. The sheet lines of each county are set out without regard to those of neighbouring counties, thus greatly intensifying the difficulty of making a map of any area of ground which is situated in more than one county. There is no reason whatever why the sheet lines running east and west should not be continuous across the full width of the kingdom.

The most conspicuous defect of the Ordnance maps of all scales is their obsolete character. The long neglect of revision has brought the survey into a condition of all but hopeless muddle. Large sums of

money are voted for revision every year by Parliament. No less a sum than £140,000 having been voted for this purpose in the last session of the late Parliament. As a matter of fact not one penny of this money is being spent upon true revision. It is used for new works entered upon apparently at the instance of the officials or of the Treasury. Works which, however necessary, were never contemplated by any of the committees which have sat to investigate the business of the Ordnance Survey. These are the survey of Lancashire and Yorkshire on the 25 inches scale, and especially the survey of Ireland on the same large scale.

It is essential therefore to divide the vote under certain heads, distinctly specifying the amounts which are to be devoted to carrying out works not previously contemplated in the scheme of the survey, and the amount which is to be devoted to the proper maintenance of the maps already executed. No doubt a considerable increase in the annual vote will be required, but it will be clearly seen that the increase is for new works and not for the maintenance of the scheme recommended by the committee of 1862.

It is said that a sum of more than £500,000 will be required to bring the arrears to the limit by which the survey in no part of the country would be older than fifteen years. This work might be done on the present system, but for the permanent revision within the fifteen-years' period it is obvious that entirely different arrangements are necessary.

The Permanent Revision Department should be constituted as a separate and distinct department with clearly defined duties, and organized in local divisions: the country being divided into convenient districts of a size proportionate to the density of the population, the character of the industries, and the consequent probability of change. Large surveying operations would seldom be required if the maps were continuously maintained.

The Revision Department must be independent of all county, municipal, and local authorities generally, whether contributing to the cost of the survey or not. This is essential to secure equality and similarity in the plans and maps produced and to prevent the possibility of suspicion arising that the maps could in any way be tampered with for local or personal considerations.

The superintendent and the employees, as far as possible, should be permanently stationed in their various districts. The advantage of working in conjunction with local societies has been amply demonstrated by the assistance rendered to the survey by the Royal Scottish Geographical Society. There are plenty of local societies scattered up and down the

kingdom who would be equally willing and capable of giving assistance to the survey in their respective localities. There would be no difficulty in getting a small council of competent gentlemen selected by these societies to voluntarily assist the superintendent of the district in the correct naming and description of its topography and antiquities, etc. There can be no doubt that these societies would gladly assist in this way, as it would give increased interest and utility to their work and improve the maps by preventing mistakes which now occur from want of local or special technical knowledge.

It is probable that at the present time, in districts where the maps are old, the sum which is spent by municipalities and local authorities in surveying operations is quite as great as the annual cost of a proper and adequate revision, but the results of their work are not available for general use as they would be if undertaken by a Government Revision Department. It should not be difficult to calculate what would be a fair amount to ask as a contribution from towns of various sizes. The balance of the cost of the Revision Department would be made up by contributions from other sources, and, if necessary, from the Parliamentary grant. When the arrears are brought up it should not be difficult to devise some arrangement with the towns and localities for the maintenance of the survey, which would be equitable to them and to the Imperial exchequer.

A source of revenue for the Revision Department would be available if its services could be obtained by companies or individuals requiring corrected copies of any map between the issue of editions. For example, the promoters of public and private schemes of improvement, water supply, roads, drainage, railways, etc., could be provided with plans corrected in manuscript to date on payment of fees proportionate to the amount of correction required. The department would thus be paid for obtaining information which it could afterwards use in the publication of new editions.

The Revision Department being localized would soon acquire information of important changes in the district. By noting and surveying such changes at once, and correcting the official depôt-copy of the map, it would be in a position to supply almost at any time tracings of any portion of the district with corrections practically up to date to those willing to pay for the information. If the edition of any map became exhausted before the expiration of the fifteen-years' period a new corrected edition could be at once published. Thus where the demand for maps was greatest new and correct editions would be most frequent.

This scheme applies particularly to the town plans and the 25 inches maps. The publication would be done at Southampton as at present. The headquarters there, being supplied with the latest information of the changes, would have all the materials for the production of fresh editions of the 6 inches maps whenever necessary.

The further contouring and levelling which is required would be done by the present levelling division. Each superintendent of a revision district should, however, have a leveller attached to that district and under his orders, and would be responsible for the maintenance of an adequate number of bench marks, for the insertion of levels on new roads, and for the slight rectifications occasionally required in contours where alterations have been made on the ground.

The system which requires the execution and revision of the 1 inch and smaller scales to await the completion and revision of the cadastral and 6 inches maps has entirely broken down. A new and independent system for the collection of the necessary information for the speedy execution and revision of the small-scale maps is absolutely necessary. It is essential in maps of this class that the work should be accomplished quickly, so that the map may represent as nearly as possible the state of the country at one period, and also be carried out in a uniform style.

In 1840, Colonel Colby stated that he had deferred the commencement of the engraving of the 1 inch map of Ireland until the completion of the 6 inches, in order that he could set the full force of the engraving staff to work upon and complete it in a few years' time. Fifty years have passed away, and the work is still unfinished. The committee of 1851 stated that it had been shown to their satisfaction that a 1 inch map of Scotland might be completed in ten years. More than forty years have elapsed and the hill-map of Scotland is not yet completed. In 1872, what is called a "new hill-map" of England and Wales was commenced. Out of 360 sheets only 90 are published, and of the 90 no less than 73 are the original sheets with the numbers changed. It is obvious that this system of producing the topographical map, which is peculiar to this country, is wrong. It certainly passes comprehension why it should have been so long adhered to.

The 1 inch outline map is useful for many purposes—administrative and professional—but owing to the style of execution, and the attempt to make it serve as a substitute for a topographical map, it is very confusing.

On a scale like the 1 inch several forms of the map are desirable, and there is no difficulty in printing editions at various stages.

It has already been said that many of the chief defects of the survey

maps, especially of those on the larger scales, are due to the neglect of revision. There is certainly, when we remember the immense number of plans, a great deal of work to deal with; but when the decision was made to carry out the survey on these large scales, it was manifest what the number of sheets would be; and the department has had nearly forty years in which to think out the details of a system and organization adequate to cope with the work. Every year that passes only increases the difficulty of the task which has to be faced. The Treasury has again and again refused to sanction revision, although a large sum is annually voted ostensibly for the purpose, whilst it has authorized enormous and expensive undertakings without regard to the sufficiency of the vote to complete and maintain the surveys and maps already authorized. It is necessary to lay down, after proper enquiry, distinctly the lines which are to be followed by the survey in the production and maintenance of the maps. That being done, and the cost of completing and maintaining the various maps set forth clearly in the estimate presented to Parliament, there is little doubt that Parliament will grant the money necessary to save a great scheme from the disaster which is impending if steps be not soon taken to avert it.

Mr. W. Cochrane (Newcastle-upon-Tyne) asked whether in the term "revision" Mr. Crook meant that re-survey was involved, or whether it was office work from which any of those portions could be produced? Such an amount of money as a quarter of a million a year must astonish them if the result continued to be "how not to do it." It was new to him to have in such a concentrated form the mistakes which were being made. The sooner weight was brought to bear on the responsible authorities to enforce a uniform system the better. He should like to know whether records existed from which office work alone would produce everything they required.

Mr. Henry Lewis (Nottingham) said if Ordnance maps were to be used in mining engineering they should be on such a scale that underground workings could be plotted on them. Would it be costly to bring out a 2 chains to the inch scale for mining districts only?

Mr. H. T. Crook, in reply, said that with regard to the cost of revision and the mode in which it was done, all maps got out of date if not looked after. Forty years ago the Lancashire and Yorkshire map was made. It became a question whether the survey should not be taken on a larger scale, that they called revision, although there was a re-survey.

If they neglected revision for ten or twelve years they must have a re-survey. Probably 50 per cent. of the 25 inches maps would have to be re-surveyed. At the present moment the large sum of £140,000, which is voted for revision is being spent on the re-survey of Lancashire, Yorkshire, and London, and the survey of Ireland on the 25 inches scale. There is no true revision work going on. With regard to the production of another map—2 chains to the inch—it would be a very expensive matter indeed. They would have to draw out the whole sheet lines of the country, and plot the map on that scale. The work was in field books and would not have to be surveyed, but it would have to be plotted, and it would take an immense number of sheets on that scale. If the 25 inches scale was not suitable he was afraid it was almost too late to change it now. The only way was to get the 25 inches maps up to date, and to thoroughly remedy defects in the existing maps. Then it would be for the country to say whether it would do anything further for mining engineers.

The PRESIDENT said he had recently given evidence before the Departmental Commission on the Ordnance Survey. The object of that evidence was to ask them to publish a map that would be most useful to the colliery owners of the country. He did not go to find fault with the survey, and he did not go to ask for a new one, but one that could be made use of at every colliery. He asked them to plot the survey at a scale of 2 chains to 1 inch, and publish maps at a price that would be generally acceptable to mining engineers and colliery owners. Sir John Dorington, Chairman of the Commission, promised that they would enlarge one of the plans and send it down to him (the President) for approval, he undertaking to check that by actual survey of the estate itself. From what he could understand this plan could be enlarged by photography, and one of the points submitted to him in examination was whether any little error that might be made in the production of the plans would be so magnified by photography as to make them of little value to colliery owners. Supposing there was a small error which could be represented on a large scale, the error would remain the same. He pointed out that the 25 inches scale was of little service; it was too small for plotting on. He understood that considerable pressure must be brought to bear upon the Departmental Committee before the money would be given by Parliament. He moved the following resolution:—"That whilst fully appreciating the good work done by the Ordnance Survey, and the general utility of the plans, this meeting of the Federated Institution of Mining Engineers regrets that the scales upon which they are published renders them of

little practical value for the purpose of working-plans of mines; and, further, this meeting suggests to the Ordnance Survey Department that if the plans of mining districts were published on a scale of 2 chains to an inch, with the buildings lined and the trees omitted, such plans would be of practical use for working-plans for coal-mines, and of general service for mining purposes. Further, that the Ordnance Survey Department should make it generally known that tracings from the plotted plans may be obtained from the chief office, Southampton, and also that the price for such tracings may be at a reasonable cost per sheet."

Mr. J. B. SIMPSON, in seconding the resolution, expressed his concurrence in the remarks of the President, believing it would be an advantage if the Ordnance maps were on the scale which he suggested. The amount of money spent upon the production of the maps was enormous; it would be better if it were spent upon a map that all could use. If mining engineers had been consulted they would have proposed a scale they were accustomed to use, which would be a great advantage to the mining community; and he hoped it was not too late to get some pressure to bear upon the Ordnance Survey Committee.

Mr. GEORGE CLARK (Newton-le-Willows) said he would prefer a cadastral plan to a scale of 32 yards to the inch, which was used for the plans at a large number of Lancashire collieries, and the calculations made on the large one of 10,240 square yards.

The PRESIDENT said there was no reason why the Ordnance Department should not publish a 32 yards to the inch scale. It would be a step in the right direction if they could get, in the first instance, a 22 yards to the inch map published.

The resolution was agreed to.

Mr. E. B. WAIN read the following paper on "The Longwall Method of Working as Applied to Seams of Moderate Inclination in North Staffordshire":—

THE LONGWALL METHOD OF WORKING AS APPLIED TO SEAMS OF MODERATE INCLINATION IN NORTH STAFFORDSHIRE.

By EDWARD B. WAIN.

Of the various methods of coal-getting adopted in this country the longwall system seems to be the most easily applied and modified to suit the varying conditions of the different seams and coal-fields, and except in the case of seams of a very high degree of inclination, such as are found on the western side of the North Staffordshire coal-field, there are very few to which the method, or some modification may not be adapted. Moreover, there can be no doubt that it is by far the most favourable for systematic, safe, and economical working in the great majority of the seams in the Midland coal-fields. This method of working is seen to the best advantage in the Midland inspection district, more particularly in the collieries in the neighbourhood of the Leen and Erewash valleys, where it is by no means uncommon to find working-faces in a continuous line for 1,000 yards and upwards. The term longwall is, however, almost a misnomer when applied to some of the so-called modifications of the system, where the numerous irregularities and breaks in the line of the working-face prevent full advantage being taken of the gradual sinking of the roof, which so greatly facilitates the working of the coal, and obviates the necessity of the use of explosives in workings with a continuous face line.

The author proposes to describe briefly in this paper an attempt to adapt the longwall system, in its best form, to seams varying in thickness from 2 feet 9 inches to 8 feet, and lying at an angle of 14 to 20 degs. with roofs of both soft and hard metal.

This method of working has now been carried on at the Whitfield colliery for some nine years and has proved to be an unqualified success, both as regards safety and economy.

The seams in work at present are the Ten-feet, Bowling Alley, Holly Lane, Hard Mine, and Cockshead or Eight-feet Bambury.

The Ten-feet seam, which is being worked at a depth of from 170 to 210 yards from the surface, is a strong close-grained coal without partings, about 5 feet 3 inches thick. The roof is a tender dark bind, with thin

irregular bands of ironstone, and varies from 7 feet to 20 feet thick up to a strong rock. The floor is an inferior or stool coal, 3 feet thick, in two beds, with stone partings, below which is a bed of soft fireclay 4 yards thick.

The Bowling Alley seam, working at a depth of from 170 to 220 yards, is 3 feet thick, and is also a strong coal without partings, and with strong grey laminated bind roof, and soft fireclay floor about 3 feet 6 inches thick, below which are bands of strong bind.

The Holly Lane seam, worked at a depth of from 140 to 290 yards, varies from 2 feet 6 inches to 3 feet in thickness, and is a hard coal without partings, with a strong sandy rock roof and a hard clunch floor, with a pricking of soft holing dirt 1 inch thick immediately under the coal.

The Hard Mine seam, working at a depth of from 150 to 300 yards, is from 3 feet 6 inches to 4 feet thick, and contains bands of soft and hard (blast-furnace) coal. It has a roof of tender bind with ironstone nodules, about 3 feet thick, above which is a fairly strong blue bind roof with few partings. The floor is a hard clunch with ½ inch of soft pricking dirt immediately under the coal.

The Cockshead seam, working at a depth of from 400 to 520 yards, is from 7 feet 6 inches to 8 feet 6 inches thick, and is a tender bright coal, with two partings, and irregular laps or joints in the cleat line. The roof is a strong grey bind without partings, and the floor a strong black shale with partings, with 1 inch to 3 inches of soft carbonaceous shale locally known as "hustle" immediately under the coal.

In the five seams, with their differing thicknesses and conditions of roof and floor, the same system of working is being carried out with very slight variation.

There are many difficulties in the application of the longwall system to workings in seams of the inclination above-mentioned, but the chief of these have been found to be:—

1. The tendency of the roof to slip and sink back away from the face, thus taking the working weight from the coal; and
2. The disturbance of the packs, etc., on the higher side of the level gateways, caused by the slipping of the roof.

The plans and sections (Figs. 1 and 2, Plate I., and Figs. 4 and 5, Plate II.) show in detail the opening-out operations and general method of laying out the workings as adopted in the Hard Mine and Cockshead seams, 4 feet and 7½ feet thick respectively.

After the preliminary headings necessary for shaft barriers, ventilation, and drainage have been made, sufficient coal is worked out to allow the

first packs to be built, and from this point the opening-out stall or "breasting" is carried forward with a working-face nearly in the line of full dip. Two lines of rails are laid to facilitate the loading, and in the case of the thinner seam a slant to be worked by a pony is packed in. In the case of the thicker seam, where only 10 yards is got out of the lower side, a hand winch is used, which is moved forward with the face of the level.

Special attention is paid to the building of the first packs, as it is found that when the roof cuts off at the edge of the solid coal in the level there is usually more subsidence than in the ordinary working.

The first packs in the thinner seams have to be built with *débris* brought from other parts of the mine or from the "ripping" in the solid roads. As soon as a sufficient length has been built the level ripping is commenced, about 5 feet thick of roof being taken down in the Four-feet seam, care being taken not to rip in advance of the packing. It is found under ordinary circumstances, when the workings are not disturbed by subsequent operations in over or underlying seams, that very little further work is required in the main roads except a second ripping, which in most cases only consists in taking down the small thickness of roof-dirt fractured by the blasting in the first ripping.

Chocks or wood packs, 3 feet square, are built on the higher side of the road at intervals of 5 yards, old railway-sleepers being largely used for this purpose. These are found to be very suitable, as from their shape they are easily built, and the timber being somewhat soft allows a certain amount of sinking to take place.

The packing throughout is built in sections of 4 feet 6 inches in length, cross-walls at right angles to the roadside are thus formed, and it is found that these walls are a most important factor in securing the level sides.

In the case of the thicker seam (Figs. 4 and 5, Plate II.) no ripping is done in the forming of the level, and the whole of the packing has to be made with *débris* brought from other parts of the workings; and as packs 7 feet 6 inches high are not sufficiently stable as a rule for the head side, it has been found advisable to leave 2 feet 6 inches or 3 feet of coal over the pack; this allows the necessary amount of subsidence to take place.

As soon as possible a temporary jig-brow or gate-road is put to work, and for reasons to be further explained it is necessary to work the face to a certain extent concurrently with the opening out of the level. It is not, however, advisable to carry on the regular working of the coal until a sufficient length of face is opened out, or it would be difficult to keep the continuous line and direction required in order to work the system to the best advantage.

The length of the working-faces is varied with the thickness of the coal, the rule followed being that sufficient length of face is given to each set of men to allow a web or "dressing" of coal to be got out every week or ten days.

In accordance with the custom of the district the men work in sets of six or eight, two of these being loaders. The average daily weight sent out by the two loaders varies from 18 tons in the thinnest to 30 or 35 tons in the thickest seams.

The coals are holed to a depth varying between 4 feet 6 inches and 6 feet through the whole length of the face, as shown in Fig. 1, Plate I., and Fig. 4, Plate II., in dotted lines. Starting from the gate-end the coal is taken down in each direction, and as soon as a sufficient length of face is stripped the holing is recommenced. There is practically no blasting in the coal in the stalls, as it is found that where the packing and timbering is done properly the coal is broken at the back of the holing by the weight of the superincumbent strata.

The plans (Fig. 1, Plate I., and Fig. 4, Plate II.) show the timbering and packing in detail, and Appendix A gives full particulars of the method of timbering adopted. It may be well to note here that in workings of this class there appears to be no difficulty in carrying out the suggestions of H.M. Inspectors of Mines as to drawing up of printed codes of instructions for timbering in the different seams or districts of seams. It will be seen from the plans that the working-faces are laid out with a slight dip in-bye, the direction being such that a continuous face-line is kept from the head side of the level to the out-bye end of the district. Of course this direction is controlled to some extent by the dip of the mine, as the in-bye side of the stall has to be kept so that the loader can without much difficulty push out the loaded wagon to the gate-end. In practice it is found that a gradient of about 1 in 25 is suitable.

The gate-roads are laid out as nearly as possible at right angles to the line of the working-face, so as to allow the packs to have an equal bearing under the roof, which is invariably broken in lines parallel to the face-line.

The whole of the work in the stalls, timbering, packing, road laying, and ripping the roof in the gate-road, is done by the stallmen, who also deliver their coal at the bottom of the jig-brows. In the case of the main levels the coal is put into the nearest shunt, a distance not exceeding 100 yards, by the stallmen.

In all longwall working the great object aimed at is so to control and regulate the pressure of the roof strata as to keep a continuous, or as it is

generally called "travelling" weight on the coal, thus reducing the labour of holing and breaking down the coal without the necessity of blasting, care being taken not to crush the face of the coal.

In flatter seams this is comparatively a simple matter, as with moderate care it is quite easy to control the roof with the packs and timbering, but as the inclination increases there is considerable difficulty in preventing the broken masses of the roof gravitating away from the coal in the direction of the dip of the measures, and either sinking in front of the face-line, or bringing excessive pressure to bear on the edge of the coal face.

A good example of this is shown in Fig. 9, Plate II., which is a section taken in a stall where, owing to careless packing, the roof has slipped downhill, and thrown excessive pressure on the edge of the coal, which is rendered so friable that it cannot be holed, whilst Fig. 8, Plate II., shows how in an adjacent working-place in the same seam the coal is strong and firm and broken off at the back of the holing.

It will be seen that unusual attention must be given to the timbering and packing in order to work the system to the best advantage in inclined seams, but there are also several other important factors to be considered, amongst which the position of the face-line as regards the dip of the mine, the regular and systematic holing of the coal, and frequent advance of the working-face under fresh roof, are perhaps the most important.

In setting timbers it is found advisable to underset, that is, to fix them at an angle several degrees less than at right angles to the dip of the mine. By this means a certain amount of "sprag" is given to the timber, and this tends to prevent the roof slipping downhill. It will be easily understood that when timber is set exactly at right angles to the dip, the slightest slip downhill in the head of the prop renders it practically useless as a support to the roof.

Fig. 6, Plate I., and Figs. 7 and 8, Plate II., show the line of the regular-weight breaks in three of the seams, and it will be seen that these are nearly at right angles to the dip of the mine, thus clearly fixing the line of greatest pressure when the work is being properly and systematically carried out. But when in addition the pull due to the gravitation downhill is considered, it will be seen that in order to throw the pressure forward in advance of the face-line it is necessary to sprag the roof just as it is necessary to sprag the coal while holing. At the same time it must be remembered that this can only be done to a limited extent, and that if it is attempted to support too great an area of roof the timber will be broken. For this reason the timbering is kept within the smallest

possible limit, so that without using an excessive quantity of timber, the roof from under which the coal has been recently worked is kept well supported, and the wastes are allowed to break down within an easy distance of the face, so as to get a good supply of packing material within reach, at the same time preventing excessive pressure from being thrown on the timber by the sinking of the roof in the wastes.

It is of the utmost importance that the posts should be set in proper line, so as to assist in breaking the roof parallel to the face-line, and that the rows of posts should be set in exact line at right angles to the face, so that each post in the three rows used is in the best position to help the next, which would not be the case if the posts were triangulated as is the custom in some districts. The row of timber close to the face is also of great importance in preventing the roof from "cutting by" or sinking in front of the coal. It will be seen from Fig. 1, Plate I., and Fig. 4, Plate II., and by reference to Appendix A, that the breadth of roof supported on timber varies from 4 feet 6 inches to 9 feet, and that the timber is only left in the 9 feet breadth for a very short time after the coal is got down, as the lower row of props is withdrawn as the work progresses. When the fall of coal is got out the third row of timber is brought forward and set between the two rows (4 feet 6 inches apart) between which the wagon road has been carried. By this means the timber is constantly and regularly moved forward from under the broken to the more recently exposed portion of the roof. The three rows of posts in the 4 feet 6 inches breadth are an effectual support whilst the packs are being carried forward, and as 2 feet 3 inches is the maximum distance between the posts when they have to be withdrawn, there is much less danger in taking them out than there would be if they were set at greater distances.

The face packing, which is an important factor in all longwall work, is in inclined seams especially important, and needs the most careful attention. As soon as possible after the fall of coal is got out the packs are carried forward as near to the face as they can be built without obstructing the ventilation. It is necessary that they should be kept in a continuous line from the level side forward throughout the work, and where from special circumstances it is found necessary to start new packs in the wastes during the progress of the work, it is found advisable to build good solid wooden chocks as a support to the first few yards of building.

The packs have to be very carefully built of the strongest available material, and each section of the packing should be carried square and solid up to the roof and securely wedged. The best packing material is

found in the roof dirt itself, as it is only in rare cases that the floor dirt or "warrant" is sufficiently strong for the purpose. If soft material is used for filling, the packs do not offer sufficient resistance to the sinking of the roof to cause it to break down in the wastes and so relieve the excessive pressure on the coal face. The size of the packs and wastes is of course regulated by the nature of the roof, care being taken that the wastes are sufficiently wide to allow the roof to break down easily; in exceptional cases it may be necessary to use timber chocks in the wastes, and these are shifted forward in the same manner as the props.

The direction of the face-line is a matter of some importance. With faces laid out, as shown in Fig. 1, Plate I., and Fig. 4, Plate II., the angle of the dip is reduced, and the tendency to slip is also considerably reduced, and as there is a dip in-bye in the face-line, a certain amount of lateral pressure is carried on to the coal. Care, however, has to be taken that the lower stalls have a certain relative amount of lead, as shown in Fig. 1, Plate I., at the point E, so that the break from the next stalls above will not travel too directly on the line of the working-face below as it advances, but will be steadied by the packs.

Systematic holing and regular progressive advance of the working-face are essential points in the successful working of the system. Fig. 1, Plate I., and Fig. 4, Plate II., show how the holing is followed up. As soon as a sufficient length of face is stripped to allow the holers to work, the holing is recommenced at the gate-end and kept up close behind the loading-place. This is most important, as the face is spragged as soon as possible, and instead of the coal being crushed on the face-line the weight is carried forward and greatly reduces the labour of holing. When this work is not done systematically, and the face is allowed to stand after the fall of coal is got down, the roof is liable to cut by and sink in front of the coal; and as the pressure on the floor is removed in the waste and is still acting at the new face-line, it is found that the floor lifts as shown in Fig. 8, Plate II. From these two causes it follows that unless the work is kept regularly progressing the coal will be much more difficult to work, and in the case of a tender seam will be badly crushed.

When the holing is followed up as described there is no interruption in the coal-getting, as whilst the fall of coal is being got out through the whole length of the stall the next fall is being prepared, and this greatly facilitates regular and progressive working.

In laying out workings in inclined seams it is natural that the main haulage-roads should be made as far as is practicable in a level course, and

one of the points which has required considerable attention in carrying out the longwall system has been the difficulty in maintaining the main roads when so laid out. The pack walls on the higher side of the level are in the position where the tendency of the broken roof to slip downhill is soonest felt, and unless proper precautions are taken to prevent that movement they are very liable to be pushed out. When such a result follows the expense incurred in maintaining the roads is largely increased, and it is hardly possible to keep them of sufficient width for haulage purposes, particularly where double lines of rails are required. Fortunately, however, it is possible to carry on the work in such a manner as to entirely prevent any disturbance due to the ordinary working affecting the level side packing. The essential points to be considered are:—(1) That a sufficient breadth of coal is got out below the level side and well packed; (2) that as the opening-out stall or "breasting" progresses steps are taken to continue the head side working as soon as possible; and (3) that the head side pack is so built that the pressure of the roof is met by greater resistance on the level side than on the portion of the same pack nearest the working-face.

In deciding what breadth of coal should be worked on the lower side of the level, it is necessary to be guided largely by the direction of the first breaks in the roof, both on the rise and the dip side of the opening-out stall; and it has been found that the direction of these first breaks varies considerably from the direction of the main breaks, which are due to the working weight in the subsequent coal-getting operations in the stalls.

Fig. 2, Plate I., and Fig. 5, Plate II., show in section the average line of the first breaks in the two seams which have previously been generally referred to for the purpose of illustrating this paper. The reason that it is necessary to consider the direction of the first breaks rather than the main breaks is that, as the first fracture of the roof takes place soon after the packing is built, and before any general pressure due to a uniform subsidence has taken place, the packing, however carefully built, is not in condition to meet any sudden or violent disturbance.

It is shown on Fig. 2, Plate I., where only a narrow breadth of coal is got out on the lower side of the level, that as soon as the ripping is taken down in the road all lateral support is removed from the mass of broken roof *a b f*, which would then have a tendency to slip downhill. It will also be seen how much more readily the slipping would take place if a sufficient breadth of coal were not worked out on the higher side of the pack, and if the first break should take place in the

line *g h*. When, however, a sufficient breadth of coal is got out on both sides of the roadway to cause the breaks to take the lines *b d*, *d e*, there is sufficient lateral support left in the loosened mass of roof *b d e* to prevent the downhill slipping, and at the same time the greater weight of that portion directly overlying the head side packing tends to exert a more directly vertical pressure. In practice it is found that these results are actually obtained.

In the case of the thicker seam, Fig. 5, Plate II., as there is no ripping done in the earlier stages of the working it is found practicable to reduce the breadth of the deep side taken out, and it will be seen that there is about the same amount of lateral support with 10 yards of deep side worked and no ripping, as there is with 20 yards in the case of the Four-feet seam after the 5 feet thickness of roof has been ripped down in the level. In addition to the above precautions it is also possible to greatly reduce the tendency of the roof to slip by building the head side level pack so as to offer greater resistance to the pressure of the sinking roof on the roadside than on the rise side of the same pack. This is effected by means of the wood chocks, and by setting the head side row of timber to act as sprags, thus greatly assisting this side of the pack.

The other portion of the packing being built in the ordinary manner, it is found that there is a greater amount of sinking on the upper side of the pack. This is shown in Fig. 3, Plate I., where it will be seen that the packing, originally 4 feet high, has been pressed down to 3 feet on the level side, whilst on the rise side of the same pack it is only 1 foot 6 inches, showing a sinking of 12 inches in the first, and 30 inches in the latter instance. This is partly due to the extra strength of the support on the roadside, but also to some extent to the area of unsupported roof in the wastes above, between the rise side of the pack and the first break at the face-line.

The immediate effect of this unequal sinking is to reduce the angle of repose of the roof in and immediately above the level road, and it naturally follows that the tendency to slip will be greatly reduced. It is found that in roads where the original inclination is 16 degs. to 17 degs. the angle with the horizontal is reduced as much as 6 degs. in a very short time after the coal has been worked.

This experience might fairly be taken as an illustration of how it is possible to control the roof where it is required to keep the weight forward, as in the case of the stalls already described.

It is hardly possible to enter fully into all the details of the working within the limits of this paper, which has already run out to greater

length than was originally proposed; but there is one other point which appears to call for special comment, and that is the variation of the angle of the main weight breaks in the different seams, as shown in Fig. 6, Plate I., and Figs. 7 and 8, Plate II.

It will be seen that in the first instance, in a seam working at 200 yards deep the angle is 5 degs. less than at right angles to the dip of the mine; in the second case, at 280 yards deep the break is exactly at right angles to the dip; whilst in the third case, at 470 yards it is found to be 6 degs. more than right angles. Intermediate measurements under similar conditions to the last mentioned, but at 400 yards deep, show 2 degs. more than right angles.

It might be argued that the variation is due to the different nature of the roof in each case, as when the roof is more easily broken it would naturally show a more vertical fracture. This is hardly likely to be the cause in the instances illustrated, as the roof of the lower seam is of a relatively stronger nature in each case.

It would appear from this that with the greater pressure of the superincumbent strata at the greater depth the roof is broken in a more vertical direction, and that this variation is progressive. This is to some extent borne out by the author's experience in the deeper breadths of the same seams, and if it be proved that this is a natural result and not due to accidental circumstances, then some of the difficulties of longwall working in inclined seams will be considerably lessened.

In dealing with the whole subject the author has endeavoured to meet it in a practical manner, and has raised no theories which have not been proved in actual practice. The illustrations given are from measurements of workings in actual progress, and the angles of the breaks, etc., which have a considerable bearing on the subject, are the average in each case of careful measurements through workings of considerable area. He ventures to suggest that the subject is of great importance in view of the rapidly extending use of the longwall method of coal-getting in almost every coal-field of the kingdom.

The simplicity of ventilation, the greater proportion of round coal and increased yield per acre, the reduced liability to accidents from falls of roof and sides, and last, but not least, the very great reduction in the cost of both of working the mineral and maintaining the workings in good longwall work as compared with pillar-and-stall workings are subjects which might well be considered; but it is hardly possible to deal with them within the limits of this paper, which is intended to be simply a record of how the system has been adapted to certain seams.

In conclusion, it only remains to say there is no intention to claim that the work as described is the only example of good longwall working in the North Staffordshire district, where this system is being extensively adopted, but it may at least be given as a typical instance with perhaps some special or peculiar features.

The fact that in five seams, with widely differing conditions as regards thickness and nature of roof and floor, it has been found possible to work all to advantage on almost exactly the same lines; that considerable economy, as compared with other methods formerly adopted, has been effected in the cost of working; and that the death-rate from accidents due to the fall of roof in the coal face has been greatly reduced, has fully proved, in this case at least, that the longwall system is suitable in working seams of moderate inclination.

APPENDIX A.

WHITFIELD COLLIERY.—SPECIAL INSTRUCTIONS *re* TIMBERING AND PACKING.

NOTE.—These instructions are issued with a view to reduce the liability to accidents from falls of roof and side, and must be strictly carried out. Any person who does not comply with them will be liable to prosecution under General Rule 36 of the Coal Mines Regulation Act, 1887.

1.—There must be three rows of props in the working-faces, not more than 4 feet 6 inches apart each way (except in the Holly Lane seam, where they may be 5 feet under good rock roof). As soon as possible after a web of coal is got out, the back row of props shall be moved, and reset between the two front rows.

2.—Where the roof is tender or faulty, drift bars shall be set regularly.

3.—As soon as possible after a fall of coal is got off, the face side must be secured, and stretchers from the head side timber must be set, and the face properly spragged as soon as the loose coal is moved away.

4.—Care must be taken that sprags are properly set and stamped into the floor.

5.—Sprags in the Ten-feet, Hard Mine, and Cockshead seams must be set not more than 4 feet 6 inches apart, and in the Holly Lane and Bowling Alley seams not more than 5 feet 6 inches apart. Measurements to be taken between the timber.

6.—All persons timbering in roadways, or removing loose roof dirt, must set temporary timber, so as to make the place safe for themselves whilst repairing it.

7.—No person shall leave timber, rails, or other materials in the goaves, or other unsafe place, or use rails, sleepers, or other articles for any purpose other than that for which they are provided.

8.—As soon as is practicable after the coal has been got out, packs must be built and properly completed at once. All packs must be so built as not to obstruct the ventilation of the coal face, *i.e.*, a road not less than 2 feet wide shall be left between the pack and the face, unless the manager or under-manager shall otherwise direct.

To illustrate Mr Edward B. Wain's Paper on
of Moderate Inc

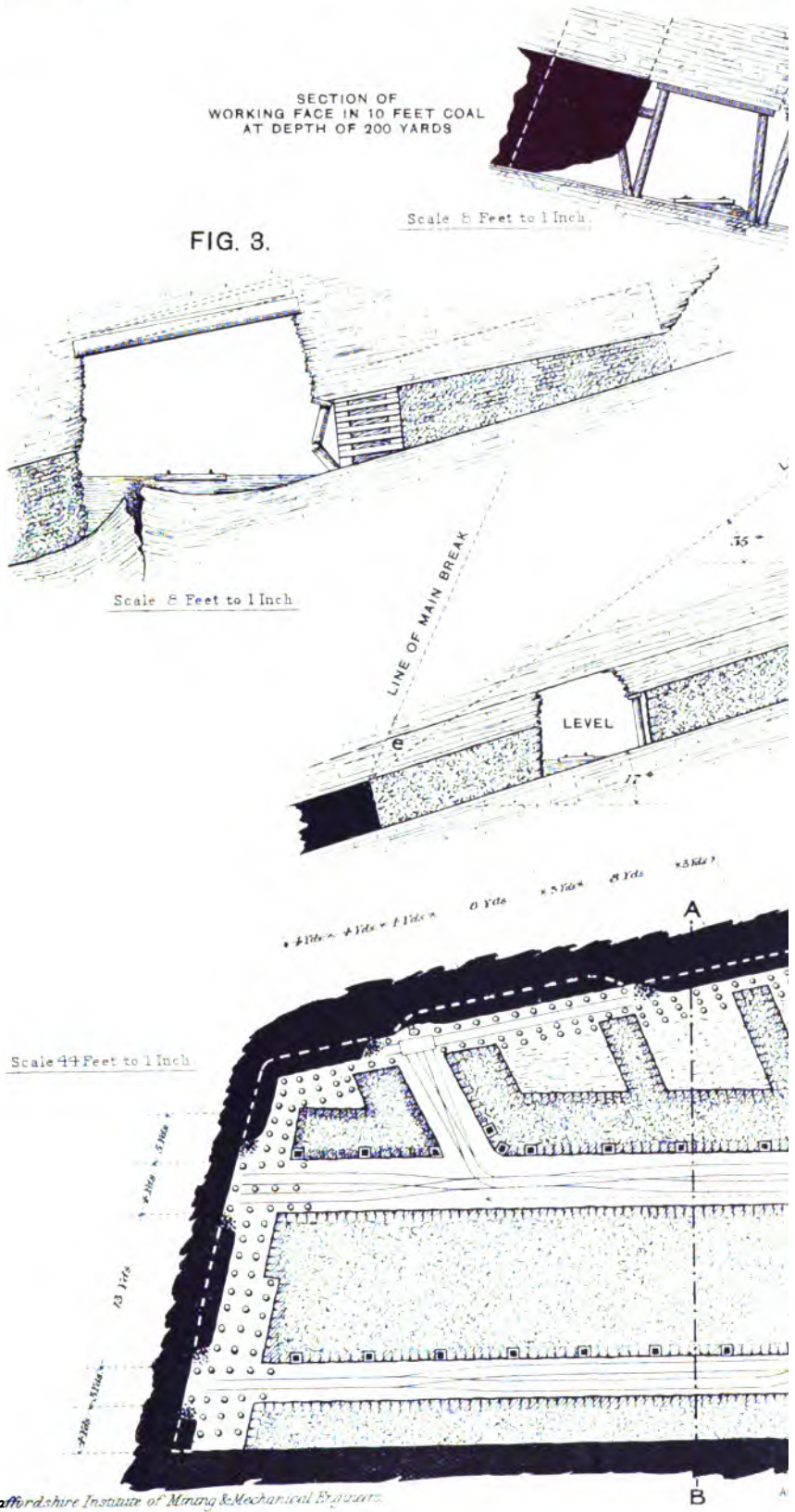
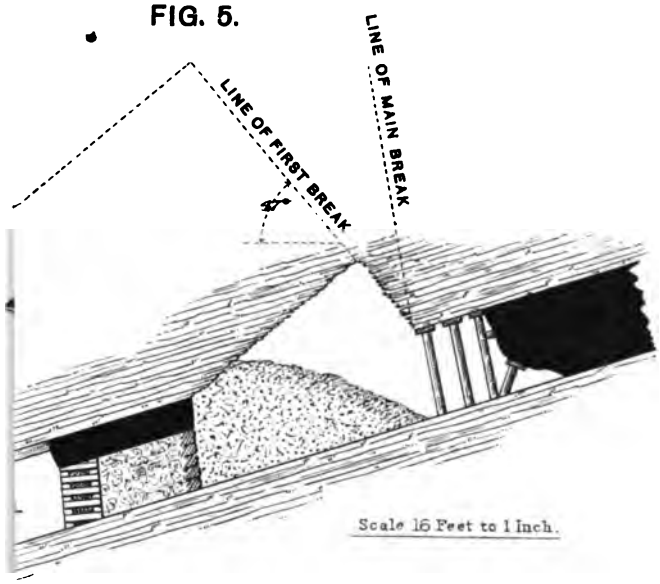
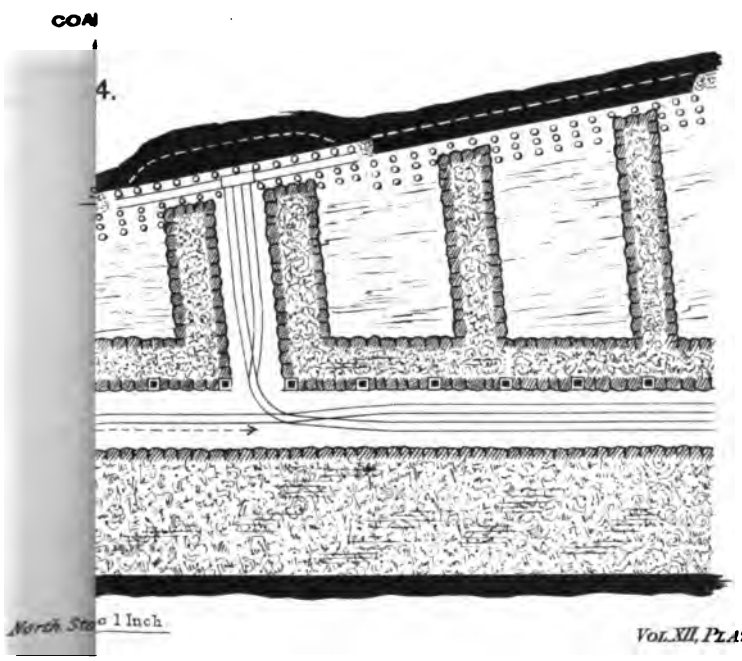


FIG. 5.



SECTION THROUGH C. D. FIG. 4.



The packs shall be built as follows:—

Name of Seam.	Dip Packs not less than	Middle Packs not less than	Wastes not more than
Ten-feet	4 yards wide	3 yards wide	8 yards wide
Bowling Alley ...	4 ,, ,,	3 ,, ,,	10 ,, ,,
Holly Lane ...	4 ,, ,,	3 ,, ,,	10 ,, ,,
Hard Mine... ...	4 ,, ,,	3 ,, ,,	8 ,, ,,
Cockshead	4 ,, ,,	3 ,, ,,	11 ,, ,,

Chocks shall be set, taken out, and reset in the wastes where it is considered necessary by the manager or under-manager.

By order,

June 12th, 1891. EDW. B. WAIN, Manager.

APPENDIX B.

PARTICULARS OF AVERAGE DAILY QUANTITY, ETC., OF EXPLOSIVES USED IN THE HARD MINE AND NORTH COCKSHEAD DISTRICTS, WHITFIELD COLLIERY.

District.	No. of Shots	Explosive.	Quantity of Explosive.	Quantity of Coal drawn per Day.		Tons of Coal per lb. of Explosive.	Cost per Ton.
			ozs.	Tons.	Cwts.	Tons.	d.
Hard Mine, levels ..	12	Gunpowder	81	43	0	8·6	1·11
,, stalls ...	5	,,	37	223	0	97·0	0·10
North Cockshead, levels	8	Carbonite	71	20	18	4·7	2·909
,, ,, stalls	0	,,	0	259	17	—	—

The quantity, etc., of explosive used in the levels may be taken as a fair average of the requirements where blasting is necessary to break down the coal; and on comparing this with the quantity used in the stalls, where the coal is broken down by the weight, one great advantage of the longwall system is readily shown.

Mr. R. T. MOORE read the following paper on "The Mineral Oil Industry of Scotland":—

THE MINERAL OIL INDUSTRY OF SCOTLAND.

By ROBERT THOMAS MOORE, C.E.

Introduction.

The capital invested in the Scottish mineral oil trade is about £2,500,000.

During the year 1891, the output of shale for the manufacture of mineral oil was 2,337,932 tons, and 5,383 persons were employed in raising it.*

An industry of this magnitude, which has sprung up within the last forty years, is well deserving the attention of the Federated Institution of Mining Engineers.

The writer proposes to notice shortly the progress and present position of the trade; the geological and stratigraphical position of the shales; the various seams of shale worked, their continuity and the mode of working; the machinery for preparing the shale for retorting; and the making of crude oil. He does not propose to go into the details of the refining of the crude oil, as this is more a chemical than a mining question.

The Scottish mineral oil industry began about 1850, when the famous Boghead mineral was brought to the notice of the late Mr. James Young, who was then engaged refining crude oil which was found in a pit at Alfreton in Derbyshire. After experimenting with it he took out a patent for the manufacture of oil by destructive distillation of coal, and erected extensive works at Bathgate, which continued to make oil from the Boghead mineral until it was exhausted.

The Boghead or Torbanehill mineral was discovered near Bathgate. It occupies a well-defined stratigraphical position in the lowest portion of the Upper Coal-measures (of Scottish geologists). The whole area over which it was worked was not greater than 1,000 acres, and the thickness varied from 2 to 32 inches. Although many trials have been made to prove the existence of the mineral in other places, it has not been found outside of the Bathgate district, and it is now practically exhausted. Many persons are familiar with the great lawsuit which was raised over this Boghead mineral. It was a matter of dispute between the landlord

* Appendix A gives the annual output of shale in Scotland since 1873.

and tenant whether it should be classed as a coal, and included in the lease as such; and an intelligent jury, after a trial in which the highest scientific authorities gave equally positive statements on either side, decided that it was a coal. Nothing has since been found to equal the Boghead mineral in richness in oil. It yielded from 100 to 120 gallons of oil per ton.

In 1864, Mr. Young commenced to make oil from the shales in the Calciferous Sandstone measures which he found at Addiewell near West Calder. About this time, several works were started to distil oil from these shales as well as from the various seams of cannel coal which are found in the Coal-measures and the Carboniferous Limestone Series; but the use of cannel coal has gradually diminished until now the manufacture of oil in Scotland is almost entirely dependent upon the shales of the Calciferous Sandstone Series.*

Geological and Stratigraphical Position of the Shales.

The Calciferous Sandstone measures, in which the oil-shales are found, are those which lie between the Carboniferous Limestone measures and the Old Red Sandstone. As will be seen from the accompanying map (Fig. 1, Plate III.) they occupy a large area in the centre of Scotland, and stretch in a south-westerly direction from St. Andrews and Dunbar on the east to Ardrossan on the west, the width of the belt varying from 30 to 40 miles.

So far, oil-shale beds have only been found in these measures in the neighbourhood of West Calder, Uphall, Queensferry, Loanhead, and Burntisland, the extreme distance between these points being 24 miles.

Shale has not been found in such large continuous areas as coal in the Coal-measures, but it exists for the most part in small basins cropping up on all sides to the surface, with a small flat piece in the centre of the basin. In some cases the outcrops are cut off by large faults. One of the largest continuous areas of shale is at Pentland, where the levels are 2 miles in length without any faults of consequence.

Occurrence of Shale Seams.

The thickness of shale-bearing strata proved is about 3,000 feet, the leading feature being the Camps or Burdiehouse Limestone, a well-known freshwater limestone, sometimes as much as 40 feet in thickness; and above and below it are found well-known seams of shale.

* About 47,000 tons of shale from the Coal-measures and the Carboniferous limestone were used for the manufacture of oil during 1891.

The following seams of shale have been recognized*:—

1. The Dam shale.
2. The Mungle shale.
3. The Grey shale.
4. The Fell shale.
5. The Broxburn shales.
6. The Dunnet shales.
7. The Barracks shale.
8. The Pumpherston shales.

Oil-shale is dark grey or black in colour, with laminated or horny fracture. Its specific gravity is 1·75, 20 cubic feet making a ton. A ready and reliable test for good oil-shale is to cut a thin paring from it with a sharp knife, and with a shale rich in oil this is found to curl like a shaving of horn.

The seams of shale vary very much in thickness and quality in different districts. Thus the Broxburn shale which at Oakbank and Broxburn contains over 30 gallons of oil to the ton, at Linlithgow contains only 19 gallons.

The shales which accompany this seam, the Big shale, the Curly shale, and the Wild shale, and which are all worked at Oakbank, are thin and unworkable at Linlithgow. The two seams of shale found below the Dunnet at Oakbank have not so far been recognized at Pentland.

In like manner the distances between the various seams vary very much. At Pentland the distance between the Dunnet shale and the Burdiehouse Limestone is only 20 fathoms, while at Oakbank a bore put down between the two seams was over 100 fathoms.

The variations in quality and thickness of seams and strata are well-known in coal-seams; but the writer thinks that the variations in the shale series are greater. This has caused many disappointments, for the best-known seams were at their best where first opened up, and so far there have not been any new seams opened up of better quality.

A general characteristic which has been observed is that the upper seams down to the Broxburn shales are richer in oil than the lower ones, while these latter are richer in ammonia. The large yield of ammonia is a special feature of the Pumpherston shales, where 60 lbs. of sulphate of ammonia per ton are got in practical working, while from some of the beds over 100 lbs. per ton can be got, as against a yield of 20 lbs. per ton from the Fell shale.

So far none of the seams has been worked under the outcrop of the Carboniferous Limestone. The nearest approach to this is at the Pentland mines, where the shales dip at an inclination of 1 in 2, and the deepest workings are 200 fathoms from the surface, and within 300 yards of the outcrop of the lowest of the Carboniferous Limestones.

* Appendix E gives a detailed section of the shale measures.

From the peculiar nature of the shale strata it is not easy to form an idea whether they exist under the Carboniferous Limestone Series, or how far they may be found to exist in other portions of the Calciferous Sandstones. Not many trials have been made by borings or otherwise in the east of Fifeshire, in Haddingtonshire, or in Ayrshire, where at some places there must be a considerable thickness of Calciferous Sandstone measures, and those which have been made have been unsuccessful.

At Lesmahagow, and in some parts of Ayrshire, the Old Red Sandstone lies immediately below the Carboniferous Limestone measures, and the Calciferous Sandstones are wanting.

Mode of Winning.

The shales have usually been worked by means of mines, commencing at the outcrops at the surface and running down in the seam to the full dip of the strata.

Coupled direct-acting winding engines are placed on the surface, and the tubs are drawn, in races of from 8 to 12, from landings in the mine, over rails weighing 40 lbs. per yard. In some cases the speed is as high as 20 miles an hour. Sometimes, where the inclination is great, the tubs are drawn up on carriages, holding four or five tubs. The tubs are placed crosswise, and in steps, so that each one stands level.

In the steep inclines the workmen are lowered and raised in a specially seated carriage, which holds eight or ten. Levels are broken from the incline at intervals of 150 yards, and each of these is a landing on the incline. These mines are found to work very satisfactorily. The main objection to them is that the drawing capacity is limited. About 350 tons per shift of 8 hours is as much as has been drawn.

The mode of working where the seams are above 4 feet in thickness is by pillar-and-stall, the pillars being made sufficiently large to be taken out in a second working. Where the seams are under 4 feet in thickness they are worked by the longwall method. The blaes forming the floors and roofs of shales are generally so soft as to be unfit for building the roadsides, and these have to be built with wooden chocks, which are removed and used over again when the road is no longer used.

Owing to the remarkable toughness of the shale it cannot be holed like coal, but has all to be blasted with gunpowder, and where there is not a holing of soft blaes, the holing has also to be made with gunpowder, large charges, sometimes as much as 2 lbs. being used in a shot. The shot-holes are put in with a rotary scroll drill. It is almost impossible to bore them with a jumper. The shale is all riddled by the miner through a 1 inch riddle, the small being left underground.

Coal-cutting machines have had a fair trial, but they have apparently been found no cheaper than manual labour, and the use of them has been given up.

The haulage from the faces is similar to that in coal-mines.

Where the inclination is greater than 1 in 2 the shale slides from the face on the floor, and runs into tubs at the level. Sometimes where the floor is soft, or the inclination is too slight, iron plates or wooden planks are put on the floor for the shale to slide upon. These spouts are not usually more than 50 or 60 yards in length.

The tubs carry from 7 to 14 cwts., and are made sometimes of wood and sometimes of iron or steel.

The quantity of water in the shale seam itself is not great, but where the workings are extensive, and "sits" take place, more water is got. The total quantity, however, is not usually great; it seldom exceeds 300 gallons per minute; but some difficulty has been found in dealing with it where it has to be pumped up the mines. At first rods were taken down the mine from the surface, or steam pumps were placed in the workings; but the breakages of the former, and the heat caused by the latter, and consequent injury to the roof and floor, have caused them, in many cases, to be abandoned in favour of the Moore hydraulic pump, which is largely used in these shale mines. At Oakbank, where the feeders are over 900 gallons per minute, there is a vertical pit 70 fathoms deep with a grasshopper beam engine, and 28 inch plungers; and at other places also where the water is heavy, vertical shafts have been sunk for pumps.

Shales give off firedamp; but hitherto they have all been worked with naked lights. The ventilation is wholly by fans, the quantities of air passing varying from 20,000 to 60,000 cubic feet per minute.

It will readily be seen that with these conditions the cost of raising shale varies considerably, the price delivered at the works being from 4s. to 6s. per ton.

Lordships (royalties) vary from 5d. to 10d. per ton of shale. In some instances they are a proportion of the crude oil yielded by the shale, generally $\frac{1}{3}$ penny per gallon of crude oil. In others they are a proportion ($\frac{1}{30}$th to $\frac{1}{40}$th) of the price of the refined products got from a ton of shale.

Where the mines are in close proximity to the works—and this is frequently the case—the tubs are run to them by chain haulage or other convenient form. Where the distance is greater the shale is emptied into railway wagons, which are taken to the works; but in no case is it taken more than 4 or 5 miles.

Preparation of Shale for Retorting.

The first operation at the works is to pass the shale through a breaker, which breaks it into flat pieces about 6 inches square. The breaker is a pair of toothed rolls, which are driven by gearing from a steam engine. The rolls are pressed together by a weight, in order to prevent the breakage of the sole-plate. Each breaker passes through about 200 tons per day of 8 hours, and there are one or more of them, according to the quantity of shale required. In the better arranged works there is usually a spare one in case of accidents.

From the breaker the shale is taken in iron tubs, holding about 10 cwts. each, to the retorts for distillation. There is usually an elevator or inclined plane with an endless chain for taking the tubs from the breaker to the level of the top of the retorts.

Making of Crude Oil.

The retorts are vertical, about 28 feet high, and arranged in benches of 80, two lines of retorts being placed back to back, like a range of coke-ovens, and rails are laid along the top, so that the tubs containing the broken shale may be run along them and emptied into the retorts. Figs. 2, 3, and 4, Plate IV., show the retort in use at Oakbank. It is the form patented by Messrs. Young & Beilby, and is now generally considered to give the best yield of oil and ammonia from the shale. Every four retorts are joined together at the top by a large casting, called a "Jumbo," which has four lids, through which the broken shale from the tubs is discharged into the retorts, and a pipe by which the gases of all the four are taken off to a main. The retorts are heated by the hard gas which comes back from the condensers, and also by coal fires, the heat being carried round the outside of the retorts by flues.

The upper part of the retort is of iron, while the lower is of brick. The lower part is kept at a bright red heat; the upper part is heated to a dull red heat. Every 6 hours about 8 cwts. of shale are put into each retort, and at the same time the spent shale is removed by a door at the bottom. Each retort holds about 30 cwts., and the shale takes about 24 hours to pass from the top to the bottom. When the shale is in the top portion of the retort, the oil is given off; when it reaches the lower portion, ammonia is given off, and to assist this, steam is passed into it at a pressure of 1 pound per square foot, at a height of 2 feet from the foot of the retort.

There are two coal fires for heating every eight retorts. These are brick retorts, the coal being fed in at the top, and burned on firebars at

the bottom. The flame from the fire mixed with the flames from the hard gas from the retorts gives sufficient heat. The quantity of coal used is from 1 to 3 cwts. per ton of shale. Each bench of 80 retorts distils 100 to 120 tons of shale every 24 hours.

The quantity of steam blown into the retorts depends upon the amount of nitrogen which the shale contains, and the refractoriness of the shale. It varies from 80 to 120 gallons of water per ton of shale.

The whole of the gases are drawn by an exhauster—generally a Baker exhauster—to condensers where the oil and the water are condensed, and taken into a separator. The water is treated for ammonia, and the oils are taken to the refinery. The uncondensed gases still remaining are passed through scrubbers, in the first of which there is medium oil, which takes out the naphtha, and in the second water, which takes out the remaining ammonia. The remaining uncondensible gas passes through the exhauster, and is taken in pipes to flues passing round the retorts, and burned in them.

This is the entire process of manufacture that is carried on in a crude oilworks, the products formed being naphtha, sulphate of ammonia, and crude oil. The crude oil is afterwards treated in the refinery, with the result that 100 gallons of crude oil produce:—

	Gallons.
Burning oil	36
Lubricating oil	10
Medium oil	13
Paraffin scale	12

But, as already mentioned, the description of these processes is beyond the scope of the present paper.

The writer has now traversed the ground from the commencement of the oil-shale industry to its present position, and trusts that he has conveyed an idea of the complicated and extensive character which it has now attained. From an engineer's and from a chemist's point of view the development has been carried out with a skill and energy which has been excelled in no other industry. He regrets that he cannot add that the industry has met with the commercial success it deserves.

Present Position of the Scottish Mineral Oil Trade.

When the manufacture of crude oil commenced, the price of burning oil, which was the sole product, was 3s. a gallon, and the trade was a very profitable one. Since then, principally by reason of the competition of American and Russian oils, the price has been steadily falling till now it is under 6d. per gallon.

The companies have struggled hard to meet the foreign foe. Other products, such as paraffin-wax and ammonia have been got from the shale, and various improvements have been introduced to lessen the loss in refining and cheapen the cost of working, but with all the improvements the shareholders of companies making oil have not had a profitable return.* Especially has this been the case during the last few years. When wages are low the cost of raising the shale is low, and the cost of coal is low, and these form a considerable proportion of the cost of production.

During the last three years, however, miners' wages have been 40 to 50 per cent. above the average, the cost of the raw material has risen while the price obtained for the products has been low, and only a few of the companies have been able to pay their way.

Whether by stricter economy or by the discovery of new processes they may be able to weather the storm is exceedingly doubtful, but it is to be hoped they may, for, as the writer has already said, it is an industry which employs a very large number of persons, and in which a large capital is employed.

It is so far fortunate that the companies are nearly all limited liability companies with a large number of shareholders, so that although individual companies have lost large sums, the losses have been spread over a larger number of persons than if they had been private companies.

In conclusion, the writer points out that shales may be sought for in other districts wherever the Calciferous Sandstones exist. Of course, this can most readily be done where the formation is not covered by the Carboniferous Limestone or the Coal-measures.

It is further interesting to note that the Pennsylvania oil and gas wells are in the measures immediately below the Carboniferous Limestone, and it is quite possible that in this country the shale strata, if bored to through the Coal-measures or the Carboniferous Limestone, may give off oil and gas.

One might almost look forward to this as a substitute for coal when the coal-fields are exhausted.

It is a matter of great scientific interest, and in the opinion of the writer, it is well worthy of the notice of those interested in the mineral development of the kingdom.

* Appendices B, C, and D show the yield of crude and refined products, and the prices realized at an oilworks since 1877.

APPENDIX A.

Outputs of Oil Shale in Scotland from 1873 to 1891.

	Tons.		Tons.
1873	524,095	1883	1,130,729
1874	361,910	1884	1,469,649
1875	424,026	1885	1,741,750
1876	541,273	1886	1,699,144
1877	684,118	1887	1,390,320
1878	645,939	1888	2,052,202
1879	712,428	1889	1,986,990
1880	730,777	1890	2,180,483
1881	912,171	1891	2,337,932
1882	994,487		

APPENDIX B.

Crude Oil Products got from 1 Ton of Shale, and Total Price realized from the Refined Products got from them.

	Crude Oil. Gallons.	Naphtha. Gallons.	Sulphate of Ammonia. Lbs.	Total Price per Ton of Shale. £ s. d.
1877... ...	30·49	—	17·37	1 3 2
1882... ...	29·84	—	13·77	0 14 4
1887... ...	27·96	—	28·95	0 11 2½
1891... ...	25·09	1·73	27·23	0 13 2

APPENDIX C.

Yield of Finished Products from 100 Gallons of Crude Oil.

	Burning Oil. Gallons.	Lubricating Oil. Gallons.	Medium Oil. Gallons.	Scale. Gallons.	Total. Gallons.
1877 ...	40·35	10·70	4·43	8·26	63·74
1882 ...	31·64	14·35	11·08	10·41	67·48
1887 ...	34·12	13·45	6·25	13·12	66·94
1891 ...	30·81	12·63	11·71	14·72	69·87

APPENDIX D.

Net Prices realized at Works for Products.

	Burning Oil. Per Gallon. Pence.	Lubricating Oil. Per Gallon. Pence.	Medium Oil. Per Gallon. Pence.	Scale. Per Lb. Pence.	Naphtha. Per Gallon. Pence.	Sulphate of Ammonia. Per Ton. £ s. d.
1877 ...	9·275	11·004	6·663	4·31	—	17 5 6
1882 ...	4·313	7·347	4·055	2·40	—	18 2 5
1887 ...	3·160	2·200	1·060	2·125	—	10 5 0
1891 ...	4·176	3·715	2·806	2·262	5·046	10 7 1

APPENDIX E.

Section of Scottish Shale Measures.

Dam or Raeburn Shale.—Formerly worked in the West Calder district.

	Ft. Ins.	Ft. Ins.
Shale	2 8	
Fireclay	0 10	
Shale	0 9	
		4 3

Strata, sandstones and blaes, 120 feet.

Mungle or Stewart Shale.—Formerly worked in the West Calder district.

	Ft.	Ins.	Ft.	Ins.
Shale (good)	1	2		
Shale (very good)	1	0		
			2	2

Strata, blaes with ribs of ironstone, 140 feet.

Two-feet Coal.—Formerly worked at Drumcross, near Bathgate, where it was a cannel coal.

	Ft.	Ins.
Coal	2	0

Strata, mostly Houston marl, 200 feet.

Grey Shale.—Worked at Addiewell.

	Ft.	Ins.
Shale	1	8

Strata, blaes with sandstones, 84 feet.

Houston Coal.—Formerly worked at West Calder, Broxburn, and Ochiltree, near Linlithgow. The section at Broxburn was :—

	Ft.	Ins.	Ft.	Ins.
Wild parrot coal	0	5		
Good coal	1	1		
Clay parting	0	1½		
Good coal	1	1		
Black blaes...	1	2¾		
Good coal	1	0		
Foul coaly blaes	0	7		
Fireclay	0	7½		
			6	1¾

Strata, blaes and fakes with 60 feet of sandstone in middle, 260 feet.

Fell Shale.—Worked at Tarbrax, Addiewell, Breich, Seafield, Hermand, and Pentland. It yields 26 to 35 gallons of crude oil and 20 to 25 lbs. of sulphate of ammonia per ton. The section at West Calder is :—

	Ft.	Ins.	Ft.	Ins.
Good shale	3	0		
Inferior shale	0	6		
			3	6

Strata, Broxburn marl, 200 feet.

Wee Shale.—

	Ft.	Ins.
Shale	2	0

Strata, blaes, 13 feet.

Big Shale.—Worked at Oakbank.

	Ft.	Ins.	Ft.	Ins.
Shale (good)	2	6		
Greystone (worked) ...	0	7		
Greystone (left)	1	0		
Fireclay holing	0	7		
			4	8

Strata, blaes, 12 feet.

Wild Shale.—Worked at Oakbank.

	Ft.	Ins.	Ft.	Ins.
Shale	2	5		
Shale	3	9		
Blaes holing	1	6		
			7	8

Strata, blaes, 10 feet.

Curly Shale.—Worked at Oakbank.

	Ft.	Ins	Ft.	Ins.
Curly shale	0	8		
Shale	2	0		
Blaes holing	2	0		
Shale	2	0		
			6	8

Strata, blaes, 5 feet.

Broxburn Shale.—Worked at Addiewell, Seafield, Hermand, Oakbank, Broxburn, Hopetoun, Linlithgow, Philpstoun, and Pentland. It yields from 19 to 35 gallons of crude oil and from 25 to 40 lbs. of sulphate of ammonia per ton. The section at Oakbank is:—

	Ft.	Ins.
Shale	5	6

Strata, blaes, 16 feet.

Lower Wild Shale.—Worked at Oakbank.

	Ft.	Ins.	Ft.	Ins.
Shale	4	6		
Blaes holing	1	0		
			5	6

Strata, with 72 feet of sandstone, 300 feet.

Dunnet Shale.—Worked at West Calder, Oakbank, Pentland, and Burntisland. It yields from 15 to 30 gallons of crude oil and 20 to 40 lbs. of sulphate of ammonia per ton. The section at Oakbank is:—

	Ft.	Ins.	Ft.	Ins.
Shale	2	10		
Blaes	4	0		
Shale	2	6		
Blaes holing	0	8		
Pugs (shale)	0	4		
			10	4

Strata, blaes, 42 feet.

Lower Dunnet Shale.—Worked at Oakbank.

	Ft.	Ins.	Ft.	Ins.
Shale (good)	5	0		
Shale (inferior)	4	0		
Shale (inferior)	4	0		
			13	0

Strata, blaes, 66 feet.

Shale.—Found in boring at Oakbank.

	Ft.	Ins.
Shale	2	4

Strata, blaes, 24 feet.

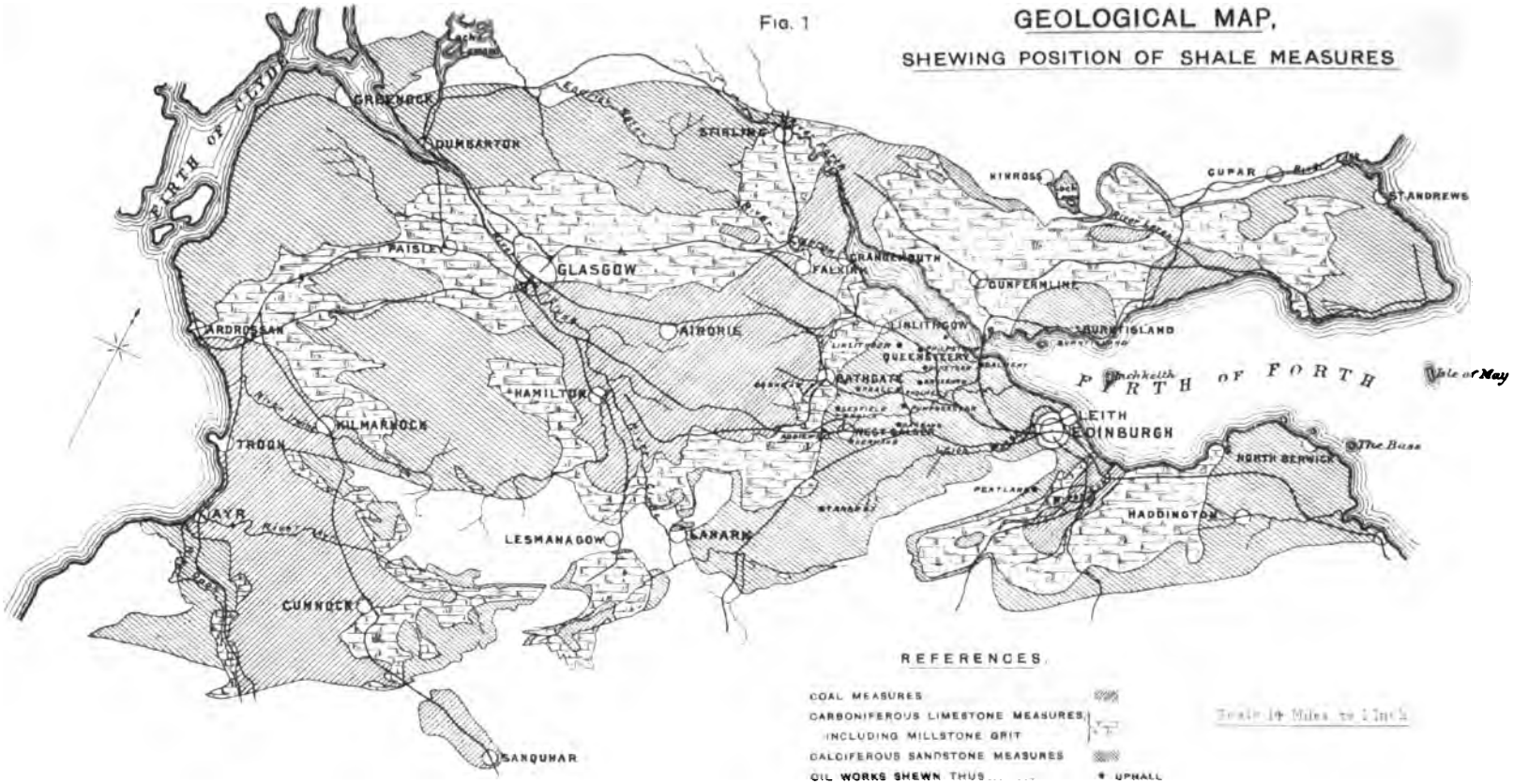
Shale.—Found in boring at Oakbank.

	Ft.	Ins.	Ft.	Ins.
Shale	5	0		
Fireclay	0	1		
Shale	2	0		
			7	1

Strata, mostly sandstones, 420 feet.

Edinburgh Institution of Mining Engineers
Transactions 1892-93

To illustrate Mr. R. T. Moore's Paper on "The Mineral Oil Industry of Scotland."



North Staffordshire Institute of Mining & Mechanical Engineers
Transactions 1892-93

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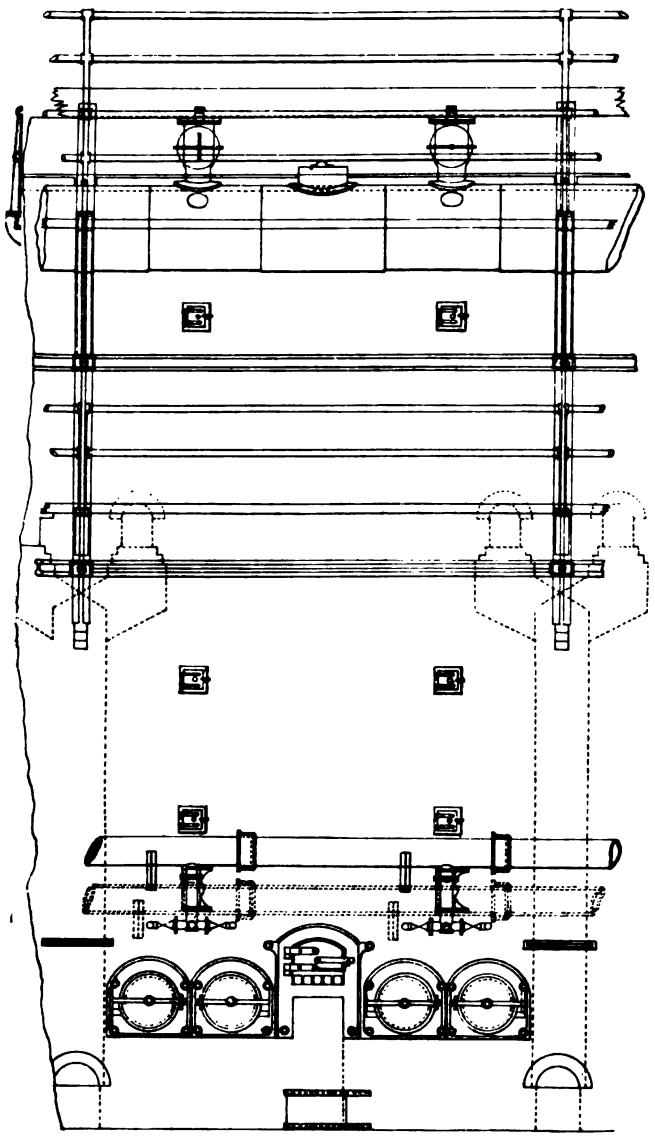

FRONT ELEVATION

FIG. 4

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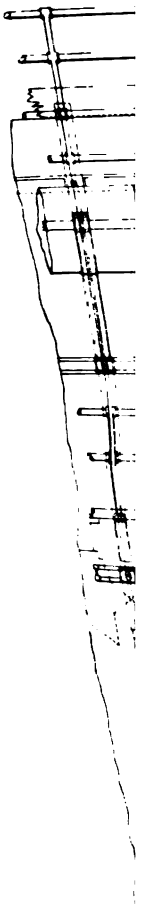
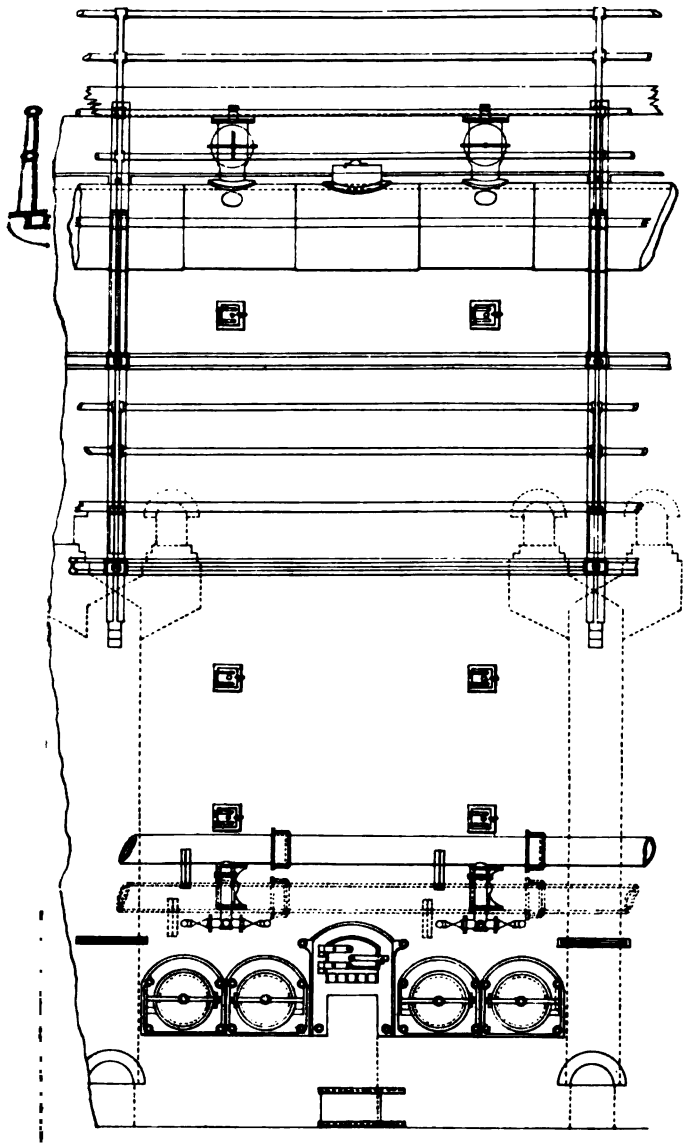




FRONT ELEVATION

FIG. 4

Barracks Shale.—Formerly worked at Deans, near Rathgate, and Linlithgow. The section at Linlithgow is:—

	Ft.	Ins.	Ft.	Ins.
Shale	9	10		
Fireclay	1	6		
Shale	4	1		
			15	5

Strata, 60 feet.

Camps or Burdiehouse Limestone.—Worked at Newpark, near West Calder, Camps, near Mid Calder, and Burdiehouse, near Edinburgh.

	Ft.	Ins.
Limestone	40	0

Strata, mostly blaes, 780 feet.

Jubilee Shale.—Worked at Holmes and Pumpherston.

	Ft.	Ins.
Plain shale	15	0

Strata, blaes, 12 feet.

Maybrick Shale.—Worked at Holmes and Pumpherston.

	Ft.	Ins.	Ft.	Ins.
Curly shale	0	3		
Curly shale	2	0		
Dirt	0	8		
Inferior shale	1	6		
Ironstone rib	0	4		
Plain shale	1	5		
			6	2

Strata, blaes, 12 feet.

Curly Shale.—Worked at Holmes and Pumpherston. It yields 19 gallons of crude oil and 60 to 70 lbs. of sulphate of ammonia per ton.

	Ft.	Ins.
Shale	7	0

Strata, blaes, 12 feet.

Big Plain Shale.—Worked at Holmes and Pumpherston.

	Ft.	Ins.
Shale	7	0

Strata, blaes, 6 feet.

Wee Plain Shale.—Worked at Holmes.

	Ft.	Ins.	Ft.	Ins.
Shale (inferior)	1	0		
Shale (good)	3	0		
Shale (inferior)	2	0		
			6	0

The blaes between the Pumpherston shales yields a large quantity of sulphate of ammonia, and are sometimes distilled along with the shale.

Mr. Ernest Craig read the following paper on "The Opening Out and Working of the Rearer Coals of North Staffordshire":—

THE OPENING OUT AND WORKING OF THE REARER COALS OF NORTH STAFFORDSHIRE.

By ERNEST CRAIG, Assoc. M. Inst. C.E.

Introduction.

It requires only a slight acquaintance with the North Staffordshire coal-field to decide that while it is exceedingly rich in seams of valuable coal and other mineral formations, it offers in their working almost every difficulty which a mining engineer in the pursuit of his arduous profession has to overcome. The numerous seams of workable coal are found from over 14 feet in thickness to less than 4 feet thick, some of which are strong coal and some tender, some fiery and some non-fiery, having every grade of roof from hard rock to brittle hussle, good floors and bad floors, dry and dusty seams, and wet and dirty seams, some liable to the danger of spontaneous combustion on the slightest occasion and others without that undesirable quality; while throughout the district, faults in all their interesting varieties are present, some being associated with measures lying flat, others standing up, with every intermediate gradient, and in some instances a seam has been known to overhang and the roof become its floor.

That these remarks are no exaggeration is shown by the section given in Fig. 1, Plate V., which represents the Podmore Hall and Apedale coal-field, a small portion of the North Staffordshire coal-field. A glance shows that the coal-field is of a most complex nature and that its working will call into practice many special methods and systems and require a great variety of mechanical appliances for hauling and ventilation.

This paper will be confined exclusively to the rearer measures. Their successful working depends more upon an accurate knowledge and observance of certain details rather than upon any system of working new or unknown to those conversant with coal-mining generally. Therefore the writer will, after briefly stating the general principles in operation, minutely describe the factors upon whose careful observance depends the success of rearer working.

Until recently seams of coal lying at an angle anywhere approaching 45 degs. from the horizontal have been considered as rearers and the rearer method of working them has been adopted. Improvements have, however, within the last few years been made in hauling, so that it has become

practicable to work coal lying at an angle of 45 degs. as easily as if it lay at 20 degs. or any smaller angle. The following observations therefore apply only to seams of coal lying at any angles between 45 degs. and the vertical, which are now classed and treated as rearers.

Rearers are opened out on the pillar-and-stall system. The pillars are exhausted from the rise downwards, the weight and gob therefore are above, the latter following the workings downwards. They are worked in what are termed breadths of not exceeding 120 yards. A breadth being the recovery, say from the top of the rearers downwards 120 yards or from the bottom of an exhausted recovery down to another 120 yards. A breadth is recovered by sinking the shaft the distance required (120 yards) and by crutting or stone-drifting from the shaft to the seam (Fig. 9, Plate V.). As one breadth becomes exhausted another must be recovered to take its place, which of course means sinking the shaft and crutting as before.

A breadth being recovered, that is, the seam being cut by the cruts from the shaft 120 yards below the exhausted workings or below the top of the rearers, as the case may be, levels are driven out on either side to within 100 yards from the boundary, at each point a pair of places are driven full rise to within 10 yards of the top of the breadth, and the main rises are then made into what are called "cage-dips." This being done, three headings are started on either side of each cage-dip; on the boundary side they are driven to the boundary, which is 100 yards, and on the other side of the cage-dip they are extended an equal distance. The coal below these levels is, for the time being, kept solid. Drifting can now be commenced, and the opening out of the breadth of rearers being effected. Before entering upon the working of the rearers there are some points which are amongst the important details referred to, to which attention can very properly be now directed. One has already been mentioned belonging as it does to the opening out, viz., the cage-dip; this and the other points are important, and as they are of vital consequence in rearer working the writer will take them in their order as follows:—(1) The cage-dip; (2) the entering-up and working of a pillar; (3) the controlling of the gob; and (4) the line of the working-face.

The Cage-dip

The cage-dip is the road from the working-faces to the main level, and is the place where the collier relinquishes his control of the coal. It is laid with two pairs of parallel roads, one pair having a broad gauge on which the cage A (Figs. 2 and 3, Plate V.) runs, and the other pair

having a narrow gauge on which the "dummy" or counter-balance B runs; at the top of the dip is the brake-wheel and gear C. The cage is a horizontal platform, placed on triangular forms, made to suit the dip of the seam (in the case shown it is inclined at 60 degs.), and running on wheels. A rope is attached to the cage at the bottom of the dip, and then taken and lapped two-and-a-half times round the brake-wheel at the top of the dip and the other end attached to the dummy in its place just below, constitutes the working appliance. The dummy is a solid casting on wheels made to overbalance the cage, rope, and empty tub, and to be overbalanced by the cage and full tub. The brake-wheel, manipulated by a lever in the hands of a youth, controls the running of the cage and dummy in the dip. An empty tub being placed on the cage and the brake eased off, the superior weight of the dummy comes into operation, and the cage and empty tub are drawn up as the dummy descends. The brake stops the cage at any landing required, say at D. The empty tub is removed and replaced by the loaded tub. The brake is eased off and the former operation reversed. The loaded tub and cage overbalancing the dummy find their way to the main-level, where the loaded tub is removed and taken to the shaft. When properly laid, such a dip seldom causes any trouble and is a most effective and cheap method of hauling.

The Entering-up and Working of a Pillar.

The pillars of coal being opened out by means of the levels at the top of the cage-dip and ready for working, entering-up is begun at the end pillars of the topmost levels. A shoulder, 5 feet in breadth, is taken off at the bottom end A (Fig. 4, Plate V.), a second shoulder B is started, and these two shoulders are gradually worked upwards, the first A, leading the second B, to the top of the pillar. As the coal is shot off it falls to the level C, where it is loaded; the face of the pillar being kept on a slant of about 45 degs. from the line of full dip for safety and convenience. Until the top pillars are to some extent worked, supposing there is no gob above, considerable scaffolding has to be done, but after a while the gob is formed and this leads to the third question.

The Controlling of the Gob.

The top pillars being advanced some distance and the gob formed, the pillar below is started, and entered-up in the manner described until it is nearly breaking through to the gob above (Fig. 5, Plate V.). A shot, S, is then put in of sufficient strength to move the gob and to start it sliding: this is called "shooting the gob." The gob being shot, it slides

down and fills the vacant space, as shown in Fig. 6, Plate V., forming a good support to work upon and acting as a means for delivering the coals to the level where they are loaded. Of course when the top shot is put in to shoot the gob, the coal coming down with that shot is lost, but this is managed so as not to lose very much coal. In case the gob does not slide, a second shot may be put into the gob itself, but this has rarely to be done. This pillar being advanced, the pillar below can be started and the same operation is repeated.

The Line of the Working-face.

The foregoing remarks show that in order to obtain the full advantage of the gob, the top workings must be a certain distance in advance of the lower workings. The top workings generally should be from 12 to 15 yards in advance of the pillar below, which pillar will be 12 to 15 yards in advance of the pillar below that, and so on in a regular line of about 50 degs. from the line of full dip. It is most important to maintain this angle of the line of working-face with the line of full dip as near as possible, and it is equally inadvisable to exceed this angle or to go below it to any great extent. In the first instance there will be crush, loss of coal, bad roads, impeded ventilation, and a dangerous gob to contend with; in the other case, where the working-faces of each pillar are too close together, the gob will not lie properly to the face, scaffolding becomes necessary, and the danger of getting the coal increases while the production reduces in quantity and the slack proportion increases.

By paying strict attention to these details rearer working can be conducted very satisfactorily.

Conclusion.

A cage-dip district when in working order will have three drifts on either side and two headings on either side; in very exceptional seams four drifts on either side and three headings on either side can be worked, and the production from the dip may be upwards of 120 tons per day. The coal must be kept as solid as possible below the working-places, only being opened out in sufficient time to take the place of the drifts as they close in on the dip. Fig. 7, Plate V., shows a rearer breadth of 120 yards and a length of level of 1,000 yards in process of opening out, and Fig. 8, Plate V., shows the recovery at its maximum production.

One other minor point may be mentioned, viz., the moving down of the brake-gear as the top pillars become exhausted. This is done once only, small pillars being left to protect it until the brake can be taken half-way down the dip, when these pillars are got by means of a screen.

It will be clear to mining engineers and managers accustomed to working flat measures that rearers present some disadvantages which are not present in other measures. The most important of which is that with a large royalty, having a length of level of say 1,000 yards, the maximum production from one pit and one seam cannot exceed 350 tons per day. This disadvantage is in a measure compensated for in North Staffordshire by the great number of workable seams, and by the fact that flat measures are found and worked in the same pit as that wherein rearers are found. Out of one pit working nothing but rearers, but having four seams in operation, there is no difficulty in producing 1,000 tons per day from a depth of 400 yards.

There are, however, some compensating elements connected with rearers that are absent in flat measures, the most important being the facility with which faults are recovered. In order to recover a fault in flat measures the miner must either go up or go down, destroying in fact the level. In rearers, the coal standing-up a fault means that the coal has been moved to the right or to the left, to the rise or to the dip, and it is recovered by turning the level in the necessary direction: a less troublesome and less expensive proceeding than dipping or raising, the level only being slightly affected for hauling purposes.

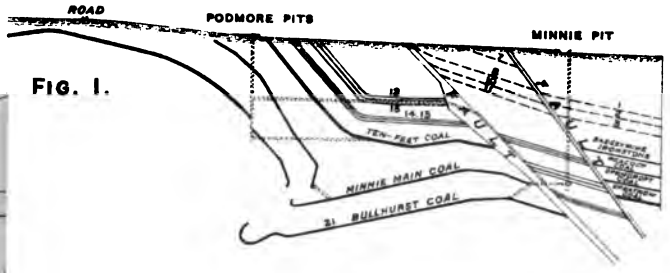
Some seams are cheaper to work when rearers, some are more expensive when rearers, and some are almost impossible to work when rearers. To this latter class belong very thick and tender coals, and those liable to spontaneous combustion.

There are many minor difficulties connected with rearer working which the writer has not considered it advisable to discuss. Every pit produces its own variety, and every manager finds himself capable of meeting them as they arise. The system that the writer has described is one which a long period of practical working has demonstrated as being satisfactory and applicable to the different seams of the North Staffordshire district, which as previously mentioned are varied in their characteristics. With the knowledge of the way in which the main difficulties of their working have been overcome an intelligent manager should be able to cope with any minor difficulties which may be met with in the working of like rearer measures.

The remaining papers were taken as read :—

rer Coals of North Staffordshire."

FIG. 1.



Scale 24 Chains to 1 Inch.

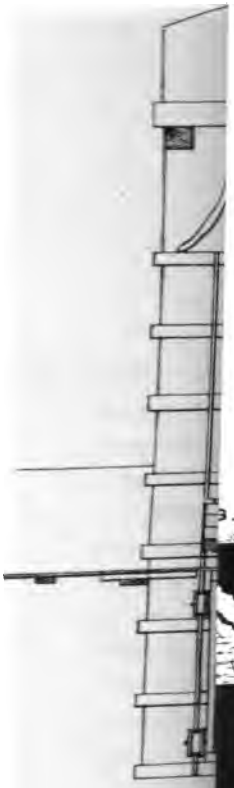
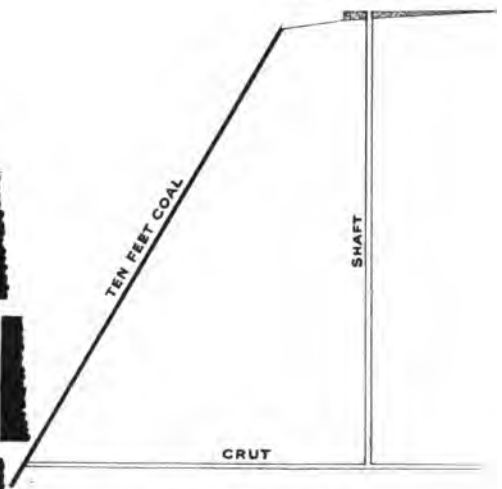
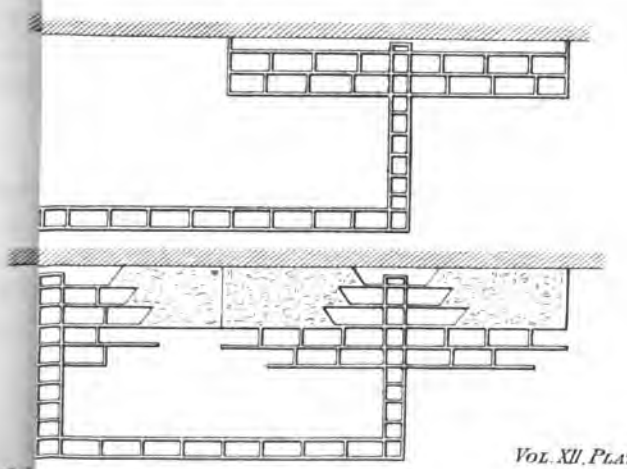


FIG. 9.



Scale 120 Yards to 1 Inch.

3. 6.



THE EXTRACTION OF MAGNETIC PARTICLES FROM AURIFEROUS AND OTHER ORES.

By WALTER B. BASSETT.

Introduction.

The demagnetizing of ores containing magnetite or magnetic pyrites has received considerably more attention in America than it has in England, and at the present moment there exist several methods of magnetic extraction in the former country which have attained more or less success in the treatment of granular magnetic ores.

The great difficulty which lies in the way of devising a satisfactory process for treating these ores is the fact that, unless the particles are thoroughly disseminated, the magnetic grains, while attaching themselves to the magnets, are apt to enclose certain of the non-magnetic granules with them, and to carry them into the portion of the apparatus destined for the magnetic grains alone. This difficulty is more acutely felt when treating magnetic pyrites or other ores possessed with only a feeble magnetic force, as the stream of magnetic particles must then be directed so close to the magnets that, unless the opposing forces are nicely balanced, there is great probability of error occurring.

When the grains vary largely in size it is preferable to screen the ores before subjecting them to a magnetizing process, as it is obvious that extremely fine grains of matter are far less susceptible to the action of any force when acting through a medium, such as air or water, than are grains of a larger size. It therefore follows that an apparatus that is perfectly capable of refining an ore, the grains of which are of fairly uniform size, will fail to do so at one operation when there is a large discrepancy in the size of the particles to be treated.

Capability of the Apparatus.

Experiments have been made on zinc slimes from a mine in the Pyrenees, where some difficulty was experienced owing to the quantity of magnetite present. In this case a successful treatment was effected by a dry process; but inasmuch as this involved drying the ores before demagnetizing them, an extra expense had hitherto been incurred. But

the results of experiments have led the writer to believe that a slightly modified machine, constructed on his principle, will be able to cope with the slimes as they come from the grinding mills, without having to previously dry them.

In the case of a sample of magnetic pyrites containing nickeliferous ores, the magnetic power possessed by the pyrites was so feeble that a stream of particles descending through water within ½ inch of a powerful magnet was not deflected appreciably, and in order to effect a magnetic separation the particles had to pass within ⅛ inch of the poles of the magnets.

For ores of this class it is doubtful whether an economical magnetic separation can be effected, as with so limited an area open to the passage of the grains, as would necessarily be the case, the plant would have to be of very large size to treat ores in great quantity.

The simplest problem by far is the treatment of the so-called iron-sands, found in many countries extending for miles along the seashore. These sands, with the exception of portions where gravel is interspersed, are made up of grains of fairly uniform size, which for the most part have their rough edges rounded off by the action of the water. The grains of these sands, possessing a specific gravity of 5, will readily sink through water, and the separation of the magnetic from the non-magnetic grains can be easily effected through this medium.

Utility of the Process.

A great deal of difficulty has been felt in many auriferous districts in dealing with the ores for gold extraction by processes dependent on the action of specific gravity, owing to the fact that the specific gravity of magnetite is so high as to cause it to remain with the gold after the washing process has been performed. It is a common saying on the west coast of New Zealand that, if you wash a panful of sand from any of the numerous streams in that locality, supposing you do not find specks of gold you are sure to find specks of magnetite at the end of the wash.

This property possessed by magnetite of remaining with the gold during an artificial washing process has its parallel in nature to a very large extent; in districts where magnetic sands abound it is almost invariably found that the richest deposits of gold-dust are those contained actually in the layers of magnetite.

Many sea beaches in New Zealand and California are composed of alternate layers of magnetite and quartz sand, and after a period of heavy gales, when the surf has subjected the sands to a continual washing, the

layers of magnetite and gold are found to be almost free from quartz sand, and the line of demarcation between the light coloured sand deposited in fine weather and the black sand before-mentioned is very plainly seen. It is at this time that the "beach-comber," as the alluvial gold-miner of the sea beaches is called, reaps his richest harvests. With his beach-box, which is a combination of amalgamated copper plates and riffles worked with a stream of water, he washes the sands of his claim over and over again, and rarely finds that gold is absent from them.

It is from these sands, when properly treated by a demagnetizing process, that the largest amount of gold may be obtained. Working on this principle the magnetite once and for all will be properly separated from the gold, and unless further deposits of gold are washed up from beyond low-water mark, as some miners believe, the whole of the sands may have all the gold contained therein extracted at a low cost and without the possibility of error.

There are miles upon miles of beach composed of auriferous magnetite in New Zealand, while the beds of many rivers are mainly made up of the same material. The Clutha, Hokitika, and Totara Rivers in New Zealand may be mentioned, the very names of which are synonymous with those of the richest auriferous districts, and the same formation occurs in many other parts of the world. In California, India, Nova Scotia, Queensland, etc., auriferous ironsands are known to exist; but hitherto the very word ironsand has been the bugbear of the digger, and has often prevented him from prospecting further with a claim known to be auriferous.

In many cases chemical processes can be substituted for the amalgamation and washing processes, but the problem as regards these may be summed up in a very few words as follows:—Will the amount of gold obtained be from ¼ ounce to 1 ounce per ton? If not, these processes may be dismissed without further thought, as the writer believes that the cost of the most modern of the cyanide or chlorination systems, with the most favourable adjuncts, cannot be brought below £1 per ton of ore treated, while many others cost a good deal more.

Analyses of New Zealand Ironsands.

At Hokitika there is 75 per cent. of magnetite; at Stewart Island there is a slightly lower proportion; while at Buller River, Nelson, no less than 87 per cent. is stated as the amount present; and anyone acquainted with New Zealand will easily call to mind beaches or beds of rivers containing magnetite in quantities closely approximating to these figures.

If the large percentages of magnetite were removed at Hokitika, the residue would be 4 times richer in gold than the sand was originally; at Buller River 4·9 times; and in parts of the Clutha River at least 5 times; whilst on many other beaches the percentage of gold would be trebled, or at least doubled.

With this important factor brought into play, chemical processes could be far more largely adopted than they are at present, as the ores to be treated would be so many times richer in gold than formerly, and therefore would be better able to pay working expenses.

Cost of the Magnetizing Process.

With electro-magnets, the cost of treatment when water-power is procurable is estimated at 1s. 6d. per ton, made up as follows:—

Attendant at turbines and dynamo, 1s. per hour, or ...	3d. per ton.
Attendant to feed sand to machine by means of a centrifugal pump, 1s. per hour, or	3d. „
Attendant to remove the refined products, 1s. per hour, or	3d. „
Depreciation of plant, repairs, renewals, balance of trade charges and expenses, taken at	9d. „

Making a total of 1s. 6d. per ton, a very small item when compared with the 20s. per ton of a direct chemical process; whilst the fact that pure magnetite is obtained as a bye-product should not be overlooked, when it is remembered that no better ore for the manufacture of steel exists than magnetite.

The Principle of the Apparatus (Plate VI.).

The mixed ore and sand from the hopper L is caused to stream over the periphery of a drum C, revolving in water in the vessel A, and presenting the polar ends of a number of electro-magnets B. Each of these magnets has its coil connected to segments of a commutator E, which revolves with the drum, and has bearing on it a pair of brushes N, connected to the terminals of a dynamo. The brushes are so arranged relatively to the commutator segments and the coils connected to them, that during the revolution of the drum the electro-magnets on the one side, where the mixture of ore and sand streams on them, are excited, attracting the magnetic granules and causing them to adhere to the periphery of the drum, while the non-magnetic sand falls away; and that on the other side the magnets are rendered inert, allowing the magnetic granules to fall away into a receptacle R_2, in which they are thus collected separate from the sand.

Thus, while the ore descends from L towards R, its magnetic particles are attracted by and adhere to the magnets, while its non-magnetic ingredients descend into R_1 and pass away through the valve K_1. The magnetic particles on being carried round to the other side of the vessel are released by the cessation of the magnetism, descend to R_2, and pass away separately from the non-magnetic particles through the valve K_2.

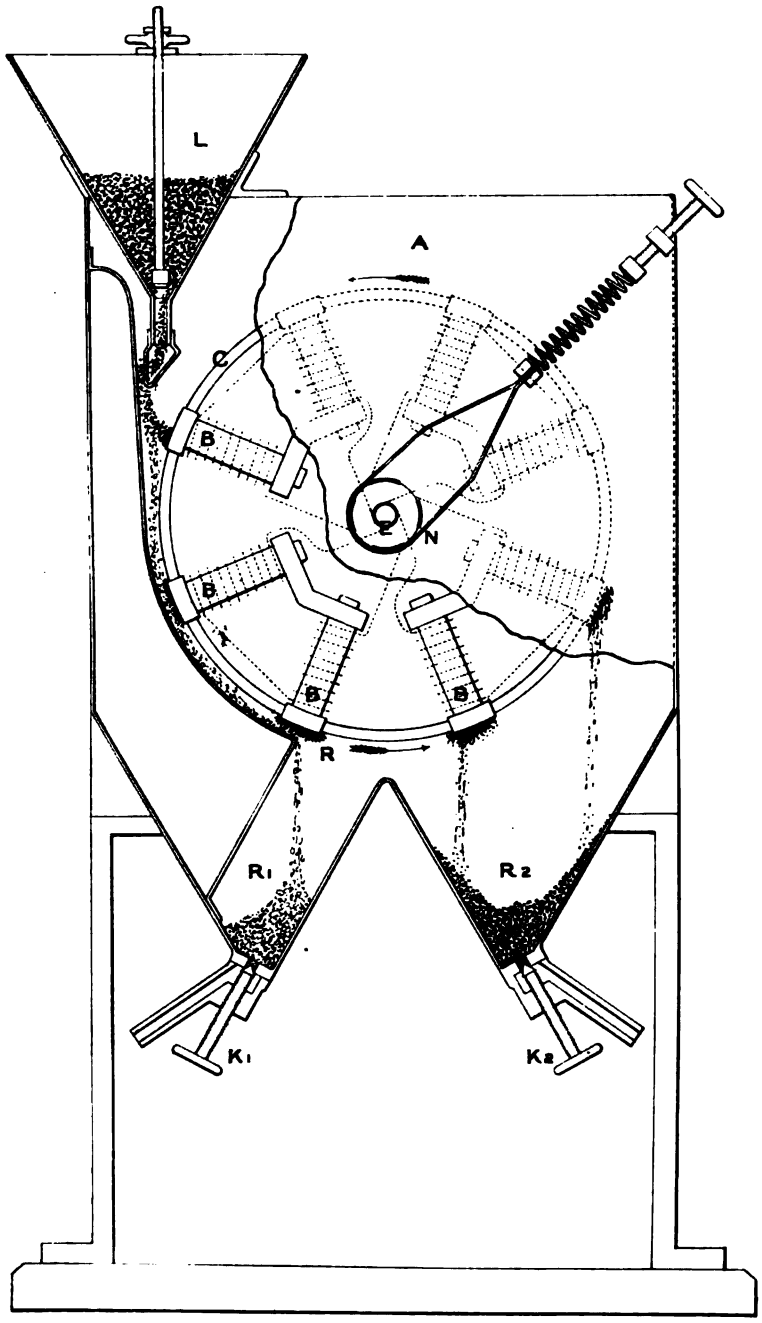
In districts where water-power is not available a somewhat similar machine may be used, but with permanent magnets; still it must be remembered that here the same factors come into play as with the field magnets of a dynamo, viz., permanent magnets cannot be constructed to give the same results as those excited by a properly proportioned helix of insulated wire, and the sectional area of the space through which the current of pulverized ore passes will have to be proportionately contracted, or in other words, the plant will have to be so much larger to give the same output.

Mr. George J. Binns (Netherseal) wrote that it was impossible to give any decisive opinion as to the merits of this machine until it had been tried on a large scale, more especially as at a recent meeting the apparatus was unfortunately (owing to an accident which could only have occurred to a model) not in working order. The writer thinks a word of caution is necessary as regards New Zealand with reference to the occurrence of auriferous magnetite wash. He writes subject to correction, but thinks that the statements contained in the following paragraph of Mr. Bassett's paper are somewhat exaggerated :—" There are miles upon miles of beach composed of auriferous magnetite in New Zealand, while the beds of many rivers are mainly made up of the same material." In this warning may also be included the mention of the Clutha River, in Otago, which, though undoubtedly a stream of surpassing richness, cannot be said to have a bed mainly composed of magnetite. Mr. Bassett is, the writer believes, unfamiliar with the district in question, and has doubtless been somewhat misinformed.

Mr. Bassett quoted, as an instance of what he had in mind when remarking that " there are miles upon miles of beach," etc., the following statement of a Government authorized surveyor in reference

to a patch of sand at Five-mile Beach, Okarito:—"It is 40 chains long by 10 chains in width by 6 feet deep (black sand only), say 387,200 cubic yards, and containing by analyses taken at several places 2 dwts., or 8s. per cubic yard, say £154,880 value of gold. This is only taken from one end of the beach." The writer would willingly give many instances of the great wealth which remains untouched, and which will assuredly yield a fortune to the man who works it with the proper appliances.

To illustrate Mr. Walter B. Bassett's Paper on "The Extraction of Magnetic Particles from Auriferous & other Ores."



MINING IN NEW ZEALAND.—(CONTINUED.)*

BY GEORGE J. BINNS.

PART II.—MISCELLANEOUS MINING. (PLATE VII.)

Since commencing this paper the writer has found that the classification originally adopted would be somewhat inconvenient, and begs permission therefore to change the title of Part II. from "Miscellaneous Lode-mining" to that given above, which is subdivided as follows:—

A.—Minerals which have been worked in the colony:—

(1) Antimony.
(2) Copper.
(3) Manganese.
(4) Tin.
(5) Scheelite.
(6) Chromium ores.
(7) Silver.
(8) Iron.
(9) Platinum.
(10) Sulphur.
(11) Graphite.
(12) Petroleum and oil-shales.
(13) Clays and sands.
(14) Building-stones.
(15) Limestone.

B.—Minerals which have not been worked in the colony:—

(1) Zinc.
(2) Lead.
(3) Mercury.
(4) Barium.
(5) Bismuth.
(6) Arsenic.
(7) Nickel.
(8) Diatomaceous earth.
(9) Asbestos.
(10) Precious stones and gems.

There are probably few countries of equal area which contain so great a variety of ores as New Zealand, but at the same time it cannot be said that the natural mineral resources of the colony have been at all worthily developed. One reason for this is the fascination exercised by gold on the mind of the miner. Familiar to him from his earliest infancy, the alpha and omega of all that is desired, he naturally inclines to search for it rather than for any of those less known and less attractive minerals containing valuable metals often in a very homely guise. Then the exceedingly rough nature of the country, already described in the first portion of this paper, has rendered the transport of bulky ores

* *Trans. Fed. Inst.*, vol. iii., page 644.

difficult and indeed often impossible. Reduction works are few and far between, and the expense attendant on treating complex minerals in bulk has usually been very great.

A.—Minerals which have been worked in the Colony.

(1) *Antimony.*

Antimony occurs widely distributed throughout the colony, from the Bay of Islands, in Auckland, to the south of Otago. In many places it is auriferous, and is worked as part of the reef, but very frequently, after extracting as much gold as can be done by crushing and amalgamation, the stibnite is allowed to flow away with the tailings. Many efforts have been made to work it, and notwithstanding several somewhat conspicuous failures the industry bids fair to become well established.

In Auckland Province antimony occurs, as already mentioned, at the Bay of Islands, and also at the Thames, Waiatohi Creek, and Coromandel.

It is, however, in Queen Charlotte Sound, Marlborough Province, that the largest deposit of stibnite has been found, and in this locality an effort has been made to work on a large scale. The discovery was made in 1878, and the analysis gave 51·12 to 69·4 per cent. of antimony. At this place the country is a fine-grained, greenish, schistose rock, changing in parts to a greyer colour, and becoming more quartzose. The lodes, of which there are three, vary a good deal in thickness and quality, and contain an appreciable amount of gold. The main reef has been followed from the north-eastern corner of the lease in a north-westerly direction for about 140 chains, and in the opposite course it may be traced on the same line of strike for about 4 miles. Its structure is peculiar, in that the stibnite forms the lode, and the quartzose part is disseminated through the ore. With the antimony are found loose blocks of olivine, with chromium ore, compact hornblende rock, and white and green chert.

A small company of Wellington (New Zealand) capitalists expended £25,000 in plant and works, including a dressing plant and smelting furnaces, but the undertaking proved to be unremunerative, and the property passed into the hands of an English company who worked on a much larger scale but with no better result. The ore appears to have been plentiful, but as is usual in such deposits was bunchy and a good deal faulted.

The dressing plant consisted, in 1890, of one Blake rock-breaker, one Marsden ore-crusher, one Lucop centrifugal pulverizer, and various

other appliances. The use of the Lucop pulverizer had been discontinued, but the Marsden crusher gave great satisfaction. Still the general result of the concentrating plant appears to have been very unsatisfactory, and the first smelting works which were erected were so inefficient that they were dismantled. During 1890, 515 tons of ore, containing from 48 to 60 per cent. of antimony, with a value of £11,121, was exported by this company, but according to the *Otago Witness* of March 24th, 1892, the mine was put up to auction in that month, and no bid was obtained. Advices dated June 9th, 1892, stated that a syndicate had purchased the mine, and decided to go on with the work.

Passing by Collingwood, where a complex antimoniferous ore occurs, which will be described under another heading, the next deposit is at Reefton, in Nelson Province, where stibnite occurs plentifully as a constituent of the gold-bearing reefs, and also near Black's Point where, at a distance of about 1½ miles from the Inangahua River, and at an altitude of about 800 feet above the stream, or 1,400 feet above the sea-level, a number of blocks occur, which have received some attention. The surface of the country is densely clad with forest and undergrowth, and consequently prospecting has been carried on under difficulties.

About 3 miles from Brunnerton, on the Greymouth-Reefton Railway, and 8 from Greymouth, quartz reefs had been known for many years, but had not attracted much attention until about the year 1878, when blocks of richly auriferous stibnite were found in the alluvium. The quartz reefs are about 600 feet above the river, and at 400 feet higher the lode from which the specimens were derived was discovered. It is about 9 feet in thickness, is included in hard blue cherty slate, and consists of five distinct bands, as follows:—

	Ft.	Ins.
No. 1, next the footwall, is quartz containing stibnite dispersed in irregular masses	2	0
No. 2, compact stibnite	2	0
No. 3, stibnite, including quartz in the form of nodules ...	3	0
No. 4, fine-grained mixture of quartz and stibnite	0	4
No. 5, breccia of slate	1	8
	9	0

The first specimens forwarded gave the astounding result of 84 ounces of gold and 36 ounces of silver per ton, or an assay value of £330. Subsequent specimens obtained by Sir James Hector did not give anything like such a good yield, the highest being from No. 2, which assayed 32 ounces of gold to the ton. Still, the prospects were exceedingly alluring, and if the reef had maintained its thickness, the results would

no doubt have been satisfactory. This was not, however, the case, and the mine was abandoned without any very decisive test of the property being made.

Other localities on the west coast, where antimony is found, are Westport, Blackball Creek, near Greymouth, and Hokitika.

In Otago, ores of this nature occur, and are now being worked, as for instance at Hindon, where a 7 feet lode occurs about 1,000 feet above the river, and has yielded 500 tons (worth £10 to £20 in London). The reefs in this locality were known in 1864, but for many years remained unworked. Recently an energetic private firm has taken up the lease, and as the lode is well-defined, and the mine within easy distance of the recently opened Otago Central Railway, the prospects should be good.

At Stony Creek, near Waipori, Otago, the antimony deposits at one time offered considerable inducement for investors, and in 1875, 60 tons of ore was sent to England to be smelted. The lode, which is composed partly of fibrous and partly of compact stibnite, is 2 feet 6 inches in thickness, and has been traced for several hundred feet. Scarcity of fuel and timber constitutes a considerable drawback to cheap working, and but little has been done.

On the Carrick Range, near Cromwell, Otago, outcrops which have been traced for upwards of a mile occur at an altitude of 3,000 feet above the sea. The reefs traverse grey foliated mica-schists, and are stated to be thin. But little has been done in this locality.

In addition to the places already named, antimony occurs widely distributed throughout the colony, as for instance in the Provinces of Napier and Wellington, and at Dunedin, in Otago, and with such quantities undoubtedly existing, the fact of so little being worked seems remarkable. One reason lies in the superior attractions of gold, and the fact that, although comparatively easy to treat, antimony ores require special knowledge and also fuel, which is often absent in the locality of the find.

The export of the ore commenced in 1878, with 4 tons, valued at £102, and reached, in 1890, 515 tons, valued at £11,121; altogether £36,190 worth has been sent out of the colony. In the year 1883 a bonus of £500 was offered for the first 250 tons of antimony regulus produced in New Zealand, and sold at a fair price in a foreign market; but no application was made, and consequently the reward lapsed.

(2) *Copper.*

Copper has been known in New Zealand since 1842, when a lode of chalcopyrite, or copper pyrites, was worked on the island of Kawau,

Auckland Province. It occurs elsewhere in various forms, as native metal in the Nelson serpentine belt; near Lake Wakatipuin, Otago; at the Great Barrier Island, in Auckland; in the Perseverance Mine, Collingwood; at Maharahara, near Woodville, North Island; and in small quantities distributed in basaltic dykes traversing trachy-dolerite breccias, near the Manukau Heads, Auckland.

In addition the following ores are found:—Cuprite or red copper ore, occurs in the serpentine belt of Nelson, where it is found yielding from 10 per cent. to 88·9 per cent. It is also found at Bligh Sound, in Otago; at Tokomairiro, Otago; and at the Thames. With it is frequently associated copper glance, or chalcocite. Chalcopyrite, or copper pyrites, which has already been mentioned as having been found at Kawau, was worked for several years, with a yield of metal at first of 16 per cent., then of 8 per cent., and finally, at the deepest point, of 5 per cent. When the mine was abandoned, principally on account of the high price of coal, consequent on the recent gold discoveries, the lode was said to be 15 feet thick. The same ore has again been worked at the Great Barrier Island, Auckland, in conjunction with peacock ore, malachite, azurite, and melaconite. At Moke Creek, near Lake Wakatipu, Otago, a lode 4 feet wide is found, consisting of 5 inches to 8 inches of chalcopyrite, and 3 feet 8 inches of gangue, with a little metallic copper scattered through it. Another locality is the Paringa River, Westland, and specimens have been obtained from the Thames, where it is associated with gold; from the Moorhouse Range (Canterbury), near Mount Cook; at Dusky Sound, on the west coast of Otago; and at Lake Ohou.

The neighbourhood of Nelson has been the site of some of the most recent attempts to produce copper, and the Champion Company, though not now in operation, erected works on a scale of considerable magnitude. The lodes seem to be of the nature of contact deposits, and occur where the red and green Maitai slates, of Lower Carboniferous age, abut on massive beds of diorite and greenstone, changing on the east into compact serpentine, with large intrusive masses of the olivine rock charged with chrome iron, and known (from the Dun Mountain) as dunite.

There are in the Champion property three lodes, known respectively as the Champion, the United, and the Maitai. The first-named consists, so far as is known, of a vein of rather soft serpentine, about 4 feet thick, between walls of compact serpentine, and contains, near the hanging wall, irregular lumps of metallic copper, with various adhering sulphides and oxides. Towards the footwall are masses of magnetite and pyrrhotine, and in some portions of the lode kernels of yellow sulphide and copper

glance (grey sulphide). In the United lode metallic copper does not occur, and the body of the lode is almost entirely composed of yellow sulphide. In the Maitai lode, which has not been much explored, the ore is mostly grey sulphide.

A large amount of dead-work was carried out, expensive roads were constructed, reducing works, with elaborate appliances, and laboratories were built, and everything laid out for complete copper mining and smelting. In all, the expenditure was about £34,000, and the average yield of all the ore produced, including native metal, was 7½ per cent., but owing to the decrease in the value of copper, the undertaking failed to pay. The estimated cost of producing fine copper was £28 to £29 per ton.

The Nelson mineral belt which has been alluded to extends from the Dun Mountain to D'Urville Island, and is covered by the Maitai series, which consists of green and purple slates (highly cleaved) and then calcareous slates, traversed by veins of calcspar, and passing eventually into a regular bed of limestone, beyond which the slates (still calcareous in character) again come in, and are succeeded by the serpentine which may be traced from the Dun Mountain to the Croixelles, reappearing at D'Urville Island. At this last-named locality an attempt to mine was made in 1878 and 1879, the deposit consisting of a true but patchy lode of copper glance. The average return from 50 tons shipped to Melbourne was 10 per cent., but the ore was imperfectly picked.

In the early fifties an English company expended large sums of money in an attempt to work the Dun Mountain copper deposits, near Nelson. The mine was 2,500 feet above the sea, and was connected with the port by a railway, 12½ miles long, with a gradient (for a large proportion of the distance) of 1 in 18. This and other extravagances, which were committed before sufficient ore was proved, caused failure. The company expired, and for many years the property lay idle. Of late years, however, an attempt has been made to re-start it, and evidence has been obtained that the original company did not pay so much attention to the indications of the lodes as would have been prudent. While these were being followed, rich deposits of chrome ore were met with, and money, which should have gone towards proving the copper-bearing lodes, was diverted. When the price of chrome fell the available capital had been expended, and operations ceased.

Near Nelson, in the Aniseed Valley, is an interesting occurrence of native copper, interspersed in minute grains through a matrix of granular serpentine. On analysis it was found to contain from 2 per cent. to 6 per

cent. of copper. A similar deposit has been found in the Serpentine Valley, lying to the south-west of the above locality, but in neither case has much been done towards proving the continuity of the bed. In the same valley redruthite or copper glance, cuprite or red oxide, and native copper occur in bunches at the Aniseed Valley Mine, but no well-defined lode is known, and at the Red Hill Mine, near Collingwood, a dark ore with resinous lustre has been found, which proved to be an intimate mixture of zinc blende, chalcopyrite, and galena.

So long ago as 1870, a discovery was made on a claim in Bedstead Gully, Collingwood, of fine specimens of chalcopyrite, and though the prospects were at the time considered to be excellent, nothing has since been done.

In Wellington Province, copper is noted as occurring at Porirua, and at Maharahara, near Woodville, and has been for some years worked. The deposit, which was first found on the slope of the Ruahine Range by Mr. Price, and consists of the native metal with various ores, is associated with red cherty rocks and hæmatite. The writer is unaware of the precise nature of the company's operations, but the March, 1892, newspapers stated that rich ore was at that time being mined.

The west coast of the South Island contains several deposits of the metal under consideration. On the Buller River, copper was found in 1874, and on the Paparoa Range in 1886; also at the Haast River a deposit is known 2 feet in thickness, and yielding 35 per cent. of copper; this is on the face of the Okura-Matakitaki Range, and within 6 miles of coal outcrops; and it is known to occur at Paringa. None of these, however have been worked, but at Dusky Sound, in the south, mining operations have been carried on. The lode here, which is 5 feet thick, consists of chalcopyrite, with pyrrhotine and magnetic iron pyrites, and yielded from 23·5 per cent. to mere traces. The associated rock is hornblende-gneiss, which varies from hornblende-rock to felspathic-gneiss, and is traversed by veins of granite. The site is only about half a mile from the shore, where there is good anchorage, but the explorations so far have gone to prove the non-existence of any well-defined lode.

In the Province of Canterbury there are, with the exception of a deposit in the Moorhouse Range, near Mount Cook, no copper ores, but in Otago—besides those occurring on the west coast, and already mentioned—are several deposits, some of which have been worked to a small extent.

About 1865, £2,000 was expended near Waipori, Otago, in a futile effort to discover a well-defined lode, and in 1862, pyritous ore containing

24 per cent. of copper was found near Ben Lomond, between Lake Wakatipu and Moke Creek. This is a true lode 1½ feet thick, dipping at an angle of 15 degs. Specimens have been found at Tokomairiro, and on the Carrick Range, near Cromwell.

It will have been observed that copper ores and the native metal are widely distributed in New Zealand, at several places in Auckland, in Wellington, through the Nelson mineral belt, at Collingwood, scattered through the west coast of the South Island, in Canterbury sparingly, and in Otago at various places. Also that the yield varies from pure metal downwards. In hardly any of these places has the working been carried out with any degree of perseverance, and in many cases, no doubt, what energy has been expended was misdirected, and the difficulties attendant upon copper smelting have militated against the success of the industry. Possibly, in future years, more skilled and determined efforts will be made.

The export of copper ore has been exceedingly variable. It commenced in 1858 with 351 tons, valued at £5,000, and has never again reached anything like the same figure. For several years, as will be seen on reference to the table (see Appendix), little or none has been exported.

(3) *Manganese.*

Manganese ores have been exported uninterruptedly since the year 1878, when 2,516 tons, valued at £10,416, was the yield, but in only one succeeding year has the original figure been equalled, and the supply shows a falling off. The total quantity is 15,303 tons valued at £51,291. During 1890, the Colonial Manganese Company produced from Waiheke Island, Auckland, 1,020 tons, valued at £2 per ton, while 150 tons valued at £2 5s. per ton came from Whangarei. Pyrolusite occurs sparingly in the colony, having been discovered in Auckland in 1873, and the only other locality known is in the same province, where the mineral was found in 1878. Hausmannite and braunite have also been noted. Manganite, psilomelane, and wad, all hydrous ores, are very plentiful; manganite in Otago, in the alluvial drift of the Kawarau and Clutha Rivers, and also an apparently extensive deposit near Taieri Mouth. An attempt was made, in 1890, to work the ore in the last-mentioned locality. In Auckland it is found at Tararu Creek (Thames), at Kawakawa, on the island of Waiheke, and at Whangarei. Tory Channel (Marlborough) and Wellington are other known localities. Wad occurs in most of the places already mentioned, and in addition to the above commercially valuable ores are found diallogite (carbonate of manganese), rhodonite (silicate), and mangano-calcite.

(4) *Tin.*

This exceedingly valuable metal has not yet been commercially worked in New Zealand. For some years the existence of tin ore in many localities had been known; for instance, in the auriferous conglomerates at the base of the Coal-measures at Lankey's Creek, Reefton, at Milford and Dusky Sounds on the west coast of Otago. A discovery was reported near Waikouaiti, Otago, in 1886, and undoubted cassiterite was brought down; but on investigation by the writer there appeared to be not the slightest indication of stanniferous rocks, and the "hardy prospector" failed to point out the locality of the supposed find. In the latter part of 1888, a discovery of tin ore took place in Stewart Island, where wash containing stream tin was found on the lower ground, and in the Remarkable Mountains cassiterite *in situ* associated with gneissic granitoid rocks. In a very few months an area of 8,280 acres had been applied for, mostly "wild-cat" claims, without a possibility of success. Of this area, 7,000 acres were taken up. By the early part of 1890, the shadow of failure had come over most of these speculations, and the intense excitement had to a great extent abated and given way to bitter regrets. The rosy prospects had faded, the rich alluvial deposits of stream tin had been proved to exist mostly in the imagination of promoters, and what little work had been done at the reefs only proved them to be unstable. The climate is excessively wet, the ground on low levels covered with an almost impenetrable scrub, and even if rich alluvial deposits existed, there is not a sufficient supply of water to afford employment to a large population. At present, the writer believes, the field is practically deserted.

Quite recently (April, 1892) stream tin has been found among the gold wash at Humphrey's Gulley, near Hokitika, on the west coast of the South Island.

(5) *Scheelite.*

Scheelite, or tungstate of lime, is remarkable for its high specific gravity (5·9 to 6·076), and for this reason attracted the notice of the early diggers. It was discovered in Otago prior to 1865 in the Buckle Burn, Rees River, also at Wakatipu Lake and Waipori, and was determined by Dr. Hector. Mr. McKay subsequently found it *in situ* on the west side of the Richardson Mountains in a reef 4 feet wide with mispickel, and its occurrence at Reefton, Wakamarina Valley, and Havelock (Marlborough) is on record, as well as at Macraes, near Palmerston (Otago), whence a second shipment has just been sent to England. In reply to enquiries recently addressed to the Colonial Government by the

Consul-General for Portugal, at Hanover, Prof. Ulrich, F.G.S., has reported that the demand is so intermittent that it does not pay to keep the mines at Lake Wakatipu open. Unfortunately no details of its export can be given as it is included in the published returns with other minerals. It is probable that ample supplies exist in the colony.

(6) *Chromium Ores.*

Chromite, or chromic iron, occurs plentifully in the mineral belt of the Nelson district, also at Jackson's Bay, in the Lake Harris Range, at Milford Sound, where a large block of nephrite was found sprinkled with it, and at Moke Creek, Otago. It is found where olivine rocks occur, and in Nelson as a constituent of the peculiarly hard variety of serpentine known as dunite, sometimes forming more than 50 per cent. of the mass. The ore is very rich, averaging over 55 per cent. of chromium oxide. In the Dun Mountain Copper Mining Company's lease a 10 feet band of the ore occurs, and one in the Roding River Company's ground measures over 15 feet in width, and has been proved vertically for 300 or 400 feet.

At one time the yield of chromium oxide was of considerable importance to the colony, the maximum having been reached in 1862 when 3,843 tons valued at £24,719 was exported. Almost immediately after that the industry became extinct, and 1866 was the last year of its existence, so far as export was concerned.*

Altogether 5,666 tons, valued at £37,367, has been exported, and it is probable that when the demand increases or the nearer supplies have become exhausted that the undoubtedly large deposits existing in New Zealand will become of value.

(7) *Silver.*

As has already been stated, the gold found in the Auckland district is alloyed to a considerable extent with silver, the latter sometimes forming 30 per cent. of the mass, and it is from this source that the bulk of this metal exported from the colony has been derived.

Quite recently a silver-mining field has been opened up at Puhipuhi, about 22 miles from Whangarei and 16 miles from Kawakawa, in the Province of Auckland. The discovery was made by gum-diggers in October, 1888; the field was proclaimed in March, 1890, and was immediately "rushed;" but, as is frequently the case, a reaction seems to have set in, partly, no doubt, on account of the exceedingly bad roads. The reefs are of varying thickness, from 7 feet downwards, and the

* On reference to the Geological Survey Reports, 1881, page 7, this information, w ich is derived from the Mines Department Report, appears to be hardly correct.

ores found comprise argentite or silver glance, pyrargyrite or ruby silver, and small grains of the native metal. Gold is found in small quantities. Mr. Alex. McKay, F.G.S., has recently visited the Puhipuhi district, and according to the Colonial papers of June 9th, 1892, considers that the field forms part of a mineralized district extending along the eastern coast of Auckland peninsula both north and south. The reefs, he states, are well defined, and prove that they live to a vertical distance of 500 to 700 feet. Almost all the leads contain silver ore, though at present the average yield is not sufficient to enable it to be treated profitably; but Mr. McKay's opinion is that the district is a legitimate field for mining enterprise.

A number of assays made from a lease known as the Prospectors' Ground gave from 200 ounces to 10 ounces per ton, and specimens from No. 3 reef as high as 2,000 ounces, while the average of nine assays was 128 ounces. The plant on the ground consisted in 1890 of a stone-breaker, one pair of Cornish rolls, a pulverizer, four amalgamating-pans, etc.

From the time the field was open, to the commencement of 1891, twenty claims had been taken up, and a small amount of work done; but, so far as the writer is aware, the bulk of the operations seem to have been purely of a prospecting nature.

A remarkably interesting and apparently valuable deposit of silver ore occurs near Collingwood (Nelson), on the Parapara River. The lode was discovered by Mr. Washbourne, and the character of the stone was determined in the Colonial Laboratory, where it had been sent for analysis as an iron ore. The containing rock is gneissic schist, passing into steatite, and farther to the west are slates and fine crystalline marble; the lode when first discovered was about 24 inches wide, and yielded from 21 ounces to 1,792 ounces of silver per ton. It subsequently increased to 5 feet in width, but the yield went down to from 22 ounces to 51 ounces per ton. At the bottom of the shaft a return of 85 ounces to 110 ounces was obtained.

The lode was sunk on for 56 feet, and driven on for 36 feet, and from the end of this drive, where the ore had changed to an argentiferous galena, 5 tons was got, which averaged 40 ounces of silver to the ton, and 3 cwts. yielding at the rate of 300 ounces. The lode in this part then became barren, and work was stopped for fear of letting in the water from the river. Other works were then carried out, which succeeded in proving that the lode was well-defined, extended over a considerable area, and was of variable thickness and richness. The ore, which has been named Richmondite, from the locality where it occurs, is a variety of tetrahedrite, and gave the following percentage composition:—

	Per Cent.
Sulphide of lead	36·12
" antimony	22·20
" bismuth	traces.
" copper	19·31
" iron	13·59
" zinc	5·87
" silver	2·39
" manganese	·52
	100·00

The mine has not been worked for some years.

In 1889, geocronite or antimonide and sulphide of lead, yielding 125 ounces of silver to the ton, was brought from Collingwood. Another deposit of silver ore, occurring at Mount Rangitoto, 20 miles south of Hokitika, merits a passing notice. On the southern face of this mountain is a lode 10 inches thick, consisting of pyrites, with about 20 per cent. of galena. A specimen brought by Mr. Cox assayed 10 ounces 17 dwts. of silver per ton; but samples tried in the Melbourne University Laboratory gave a yield of 735 ounces. The highest obtained by Mr. Skey, the able chemist attached to the New Zealand Colonial Laboratory, was 10 ounces 17 dwts.; but it must be remembered that the Melbourne University results were given on the galena, and not on the ore.

As the workings were continued the lode changed to a vein of solid pyrites, with a very little galena scattered through it.

During 1890, the amount of silver exported was 32,637 ounces, valued at £6,162, whereas in 1871 it was 80,272 ounces, valued at £23,145. Altogether since the commencement in 1869, 554,610 ounces, valued at £134,997, have been exported.

(8) *Iron.*

Ores.—The ores of iron occurring in New Zealand are both numerous and abundant, and have been divided by Sir James Hector into (1) granular, and (2) massive.

The first-named variety, that is ironsand, is very widely distributed in the colony, but the littoral deposits of the west coasts of both islands are the most remarkable; and at Taranaki the shore-line between high and low water-marks is, for great distances, composed almost entirely of this material. At the Manukau Heads also a similar formation occurs. The iron contained in this sand is present in the form of magnetite, hæmatite, or as titaniferous oxide. The magnetite is derived principally from acidic rocks, such as the granites of the South Island and the trachytes of the North; while the hæmatites or specular ores are derived from the

metamorphic schists, and the titanic oxides from the diorites and basaltic rocks.

The analyses of ironsand which have been made, give from 70 per cent. of iron; and it is a noteworthy fact that most of the sands from the South Island are auriferous.

The following massive ores have been examined :—

(*a*) Magnetite (impure) from Manukau, Auckland. This is merely black sand cemented by oxidation, and is tolerably abundant. It contains 60·2 per cent. of magnetite, 37·9 per cent. of hæmatite, and 1·9 per cent. of siliceous matter.

(*b*) Gives 86·32 per cent. of magnetite, and 13·68 per cent. of siliceous matter. It occurs in chlorite schists, in a very inaccessible part of the interior of Otago. The rock is a very compact foliated diorite, with crystals of magnetite.

(*c*) Yields 96·11 per cent. of magnetite, and 3·89 per cent. siliceous matter. It occurs in mica-schist in the vicinity of Lake Wakatipu, Otago, near deposits of limestone.

(*d*) Is found in the serpentine series of the Nelson mineral belt, on the lease formerly belonging to the Dun Mountain Copper Company. The analysis is 90·6 per cent. of hæmatite, and 7·6 per cent. of siliceous matter. The thickness of the lode, which occurs with red, grey, and blue oxides of copper, and is auriferous, was not proved.

(*e*) Is from Maramarua, Auckland Province, and contains hæmatite and magnetite, with manganese, but its percentage of silica is high.

The next four samples belong to the hydrous ores, of which—

(*a*) Is a bog ore, somewhat inferior in quality, as it contains much sulphur, 13·2 per cent. of water, and 13·83 per cent. of siliceous impurities.

(*b*) Is a brown ore, from the Tertiary coal-formation of Raglan, near Auckland, and is found in the form of balls or concretionary masses in the coal shales. The following is a detailed analysis :—

	Per Cent.
Sesquioxide of iron	72·69
Oxide of manganese	·56
Alumina	1·16
Lime	·27
Magnesia	·69
Phosphoric acid	·70
Sulphide of iron	traces.
Siliceous matter	6·30
Water { hygroscopic	4·61
Water { constitutional	13·02
	100·00

(*c*) Is a sample of the great Parapara limonitic deposit, which occurs in enormous quantities on the surface of the ground near Collingwood, Nelson. It is the hydrated ferric oxide, having the formula $2\ Fe_2O_3,\ H_2O$, and contains when pure 59·89 per cent. of iron. At this place it is found massive, earthy, botryoidal, mammillary, and concretionary, and covers the earth in large dark brown masses, sometimes of many tons in weight. On breaking these lumps there is frequently disclosed a kernel of undecomposed sulphide of iron; and Mr. Cox's opinion is that the deposit is the oxidized cap of a large pyritous lode. The writer has traced this deposit for 2,772 yards within the original lease, and is of opinion that it extends to the Onakaka Creek, a further distance of more than a mile. Interspersed among it are waterworn quartz-pebbles, which would necessitate hand-picking. A sample gave:—

	Per Cent.
Sesquioxide of iron	62·68
Manganese	traces.
Lime	·61
Magnesia	traces.
Siliceous matter	23·47
Water	13·24
	100·00

And a sample of iron made from it at Melbourne, in 1873, showed the following percentage composition:—

	Per Cent.
Iron	97·668
Manganese	·268
Carbon, combined	·542
Carbon, free (graphite)	·208
Silicon, with titanium, traces	1·004
Phosphorus	·041
Sulphur	·269
	100·000

The situation is admirably adapted for the site of an iron-smelting plant. Close to the limonite is a deposit of nearly pure crystalline marble, and 5 miles away is the Collingwood coal-mine, yielding some of the best fuel in the colony. Facilities exist for the formation of a well-sheltered deep-water wharf.

Another deposit of a similar nature has been found at Mount Peel, Nelson.

At the Collingwood coal-mine in the Upper Secondary coal-formation occur deposits of spathic ore, of which the following analyses may be given:—

	1 Per Cent.	2 Per Cent.
Peroxide of iron	35·23	40·38
Sesquioxide of iron...	25·77	5·26
Oxide of manganese	1·10	traces.
Alumina	2·11	·40
Magnesia	1·94	·63
Silica	·90	·55
Phosphoric acid	not determined.	not determined.
Sulphuric acid	traces.	traces.
Carbonic acid	21·12	21·97
Sulphide of iron	·41	·09
Water	1·96	·39
Organic matter	5·72	12·98
Silicates, undecomposed by acids	3·03	16·69
	100·00	100·00

This occurs with coal-seams which, though somewhat thin, are of excellent quality, and close to the mine is abundance of fine limestone.

Spathic ores of great purity have been found near Ashburton, Canterbury, at Foote's coal-mine, near the Miranda Redoubt (Auckland), and at Jenkins' coal-mine, close to Nelson.

In addition to these commercially valuable ores the following, which are only mineralogically interesting, are known:—

Siderite ($FeCO_3$) is mentioned as occurring in cavities of the contorted schists of Otago, and also at the Clutha, but the writer is of opinion that it must exist in considerable mass at Hindon, near Dunedin, as a specimen from a vein, which the proprietors were working as quartz for gold, was found to consist of pure carbonate of iron.

Iron pyrites is exceedingly common, and is chiefly interesting, as usually containing gold, and being associated with valuable sulphides.

Marcasite occurs among the brown coals. Pyrrhotine was discovered by Mr. Cox in 1876, near Mount Cook, and has been found in various other places.

Melanterite has already been mentioned as occurring in the gold-mines, and is also found in the collieries.

Manufacture of Iron.—Several attempts have been made to utilize these deposits of iron ore, the first being about 1874, when the Parapara Iron and Coal Company, Limited, expended £10,000, partly on the coal-mine, partly on cottages and a wharf, and partly on the foundation of a

blast-furnace. Their capital was, however, insufficient, and they went into liquidation without smelting any iron. Lately some 300 tons of the Parapara hæmatite has been sent to Auckland to be experimented on at the Onehunga Ironworks.

The granular ores of Auckland have several times induced capitalists to invest money in their manufacture, and many patents have been taken out for the purpose, but without avail. It is necessary to mix the ore with some cementing material, and for this purpose the scoria or volcanic slag, which abounds in the neighbourhood of Auckland, was at one time tried, but the result was unsatisfactory. The last company went into liquidation, and the plant was bought in by the mortgagees, who employed it in working up all the scrap they could get in New Zealand, and subsequently old iron rails bought in Queensland, which were re-rolled into pit rails. Some pig iron was made of iron ore brought from Whangarei (some 70 miles north of Auckland) by sea, after being carted 1 mile and railed 8 miles to port; it was then carried by sea to Auckland, and by railway 7 miles to the works at Onehunga. The limestone was brought from Kuiti on the Waikato River, 125 miles away. It could hardly be expected that this would pay, and, as stated, Parapara ore was next tried, smelted with coke brought from Westport and Greymouth.* The Government of New Zealand has not been backward in encouragement to the iron industry. In 1879, full particulars of the natural resources of the colony in iron, coal, and limestone, were circulated in Europe and America, and tenders were called for the supply of 100,000 tons of steel rails, manufactured within the colony from New Zealand ores. No offers were received.

In 1886, a bonus of £1,000 was awaiting the successful manufacturers of 200 tons of wrought-iron blooms, and the New Zealand Iron and Steel Company, then at work at Onehunga, was intending to apply for it. In February, 1892, the government made a further offer of a bonus of £1 per ton for the first 500 tons of pig-iron of marketable quality manufactured from ironsand in the colony, all material, fuel, and fluxes, to be the produce of New Zealand.

It is worthy of mention that the hæmatites found at Thames (Auckland) and at Parapara, are largely used in the manufacture of paint.

* The writer is indebted for recent information on the subject of iron manufacture to Mr. R. R. Hunt, of Auckland.

The *Otago Witness* of 6th June states that the latest charge is a mixture of Parapara and Whangarei ores, which will be run off early in July. Two Government officials relieve each other, night and day, to see that no scrap iron is put in.

Exports.—The official returns give the total quantity of hæmatite ore exported to the end of 1890, as 52½ tons, valued at £225, but Sir Jas. Hector's valuable "Handbook of New Zealand" for 1886, states that up to the end of 1885, the iron ore exported amounted to 209½ tons, valued at £1,066.

It will be acknowledged that iron ores of varying and sometimes excellent quality are widely distributed in New Zealand, and that first-class fuels and fluxes are often found in juxtaposition, but the scattered population of the colony and the cost of transport have militated against the manufacture. Wages also are very high, and prices in England and freights to the colony are very low. It appears to the writer that some of these factors must undergo a change before the industry can be started on a large scale with any certainty of proving remunerative. At the same time it is consolatory for those who have the welfare of the colony at heart to know that there are within its boundaries the elements of a successful metallurgical industry.

(9) *Platinum.*

Scales of platinum have been found in the auriferous wash of Foveaux Straits, and in other places in the southern gold-fields. Within the last few months its occurrence at Waipapa, Otago, has been noted. Platiniridium and osmiridium have been identified in Nelson Province.

(10) *Sulphur.*

Sulphur is found universally as a constituent of the metallic sulphides, and also in the pure state in large quantities on White Island, off the coast of Auckland. At this place it is deposited from hot springs, as on other islands in the Bay of Plenty, where it is found in smaller quantities. Among the Rotomahana and Taupo fumaroles some sulphur is found, as at several other similar localities. Work has been carried on at White Island, whenever the volcanic agencies have been sufficiently subdued to render it safe.

(11) *Graphite.*

Plumbago occurs in many localities, but never sufficiently pure or in sufficient quantity to be permanently worked. Prior to 1865, 7 tons of the manufactured article was exported from Pakawau, near Collingwood (Nelson), but nothing has since been done to continue the trade. In addition to this locality, graphite has been found in Wellington Province, at several places also in Canterbury, Otago, and Westland.

(12) *Petroleum and Oil-shales.*

Though several localities in the North Island have produced petroleum oil of a fine quality, sufficient has not yet been discovered to render the venture a commercial success.

Three places have been noted for this mineral, viz.:—(1) Taranaki, near the Sugar Loaves; (2) Poverty Bay, east coast, Auckland; and (3) Manutahi, Waiapu, East Cape. From the first-named the oil has a very high specific gravity—·960 to ·964 at 60 degs. Fahr. It is a good lubricating oil, but not suitable for an illuminant.

The oil from Waiapu resembles that found in Canada; by three distillations about 65 per cent. of good illuminating oil with a specific gravity of ·843 is obtainable.

That from Poverty Bay is a true paraffin oil. That from Rotokatuku is of a very fair quality, with a specific gravity of ·833.

So long as twenty-five years ago a company was formed to bore for oil at New Plymouth in Taranaki. A little to the north of the Sugar Loaves a hole was put down for 300 feet by hand-labour, and indications of petroleum were found with a little carburetted hydrogen gas. Another borehole was put down on Mikotahi Island, with about the same result. Another company sank a shaft near high-water mark, and at a depth of 60 feet they were driven out by gas, having at 44 feet passed through a porous stratum with a little oil. For a few weeks, it is said, about 50 gallons of oil per week was obtained here. Recently an English company, known as the South Pacific Oil Company, has been boring, and in 1891, the depth attained was 680 feet. A little oil and some gas had been met with, and the boring was proceeding. The oil had a specific gravity of ·834, and a flashing point of 93 degs.

The surface of the country is covered by a thick deposit of trachytic breccia, carrying ferruginous seams, and the places where indications of petroleum are met with appear to be included in a belt not more than 500 yards wide. In many wells about the locality small quantities of oil are found, but as yet no commercial success has been attained. The borehole mentioned above was commenced 16 inches in diameter, and appears to be carried on by American workmen.

The Southern Cross Oil Company have been boring in the Waiapu Valley, Napier, for some years, and a considerable area of oil-bearing rocks of great thickness has been found. The borehole was in 1886 at 1,700 feet, and it was intended to continue to at least 2,000 feet.

In the Geological Report for 1888 is an account by Mr. Jas. Park, F.G.S., of numerous escapes of inflammable natural gas which exist on the

east coast of Wairarapa North County, in Wellington Province, where there is a belt of oil-bearing strata from 3 to 8 miles wide of Secondary age, and consisting of shattered glauconitic sandstone, slaty shales, and sandstone, indurated marly and brecciated siliceous clays. It is considered, however, that the rocks are too much fractured to afford the requisite pressure for the condensation of the gases. A bonus of 6d. per gallon for the production of kerosene up to 50,000 gallons, in quantities of not less than 10,000 gallons at a time, was offered in 1874 and 1885, but no applications were received.

In addition to natural gases and oils the colony contains several oil-shales, of which the following may be mentioned:—

In the Chatham Islands is a bituminous peat, occurring in detached blocks of irregular form and considerable size, in the superficial gravels. It contains, after exposure to the atmosphere, 20·41 per cent. of fixed carbon, and 66 per cent. of volatile hydrocarbons. A similar mineral is found at the Auckland Islands.

A carbonaceous mineral containing 75 per cent. of volatile matter, and closely resembling torbanite, is found at Awatere, near Auckland.

An oil-shale at Orepuki, Southland, has the following composition:—

	Per Cent.
Fixed carbon	14·96
Hydrocarbons	39·39
Water	6·74
Ash...	39·91
	100·00

It is found associated with coal-seams, and an inferior, but somewhat similar, shale has been brought from Blueskin near Dunedin.

(13) *Clay and Sands.*

Clays available both for building and pottery are so widely distributed that it is unnecessary to mention localities, and the same remark may be applied to fireclays, which, at Brunnerton, near Greymouth, are manufactured by the Brunner Coal Company into most excellent bricks, retorts, etc. Kaolin is found in Stewart Island, at the Manuherikia Plains and Arrow (Otago), at Mount Somers in Canterbury, and at Whau (Auckland). Sands of excellent quality are very abundant, and in some cases they are sufficiently pure for glass-making.

(14) *Building-stones.*

Building-stones of almost every variety, of great beauty, occur in various places; but their consideration is somewhat outside the scope of this paper.

(15) *Limestone.*

Limestone is almost universally distributed. Fine samples of marble have been brought from the west coast of Otago; but a company formed about 1880 did not succeed in establishing a business. Crystalline limestone is found in other places, agriculturally useful limestone at Tokomairiro, Mount Somers, and many other localities; lithographic stones of good quality at the Abbey Rocks, Westland, and chalk at Oxford in Canterbury. Gypsum is widely known.

The above-mentioned minerals comprise, to the best of the writer's belief, all those which have been commercially extracted in the colony, with the exception of that already mentioned in Part I. of this paper, and those to be dealt with in Parts III. and IV. Other metals and minerals have been found, and will now be briefly described.

B.—MINERALS WHICH HAVE NOT BEEN WORKED IN THE COLONY.

(1) *Zinc.*—The usually-found ore of this metal is the sulphide, or zinc blende, in which form it is not uncommon. Calamine (carbonate in this case) is reported from Tararu Creek (Auckland), and from the Kaikorai Valley, near Dunedin.

Blende is found in the Thames gold-field associated with quartz, galena, copper, and iron pyrites; also at Great Barrier Island, at Te Aroha, Coromandel, Mount Arthur, Collingwood, and the Owen district (Nelson). At Collingwood the ore forms a lode 5 feet to 6 feet thick, and varies from the "black jack" of the miners, to a yellow, honey-coloured blende, containing 59 per cent. to 65 per cent. of zinc.

At Mount Rangitoto in Westland, zinc blende occurs with galena and pyrites, the former having about 4 ounces of silver, and the latter 5 ounces of gold to the ton.

(2) *Lead.*—Galena has already been mentioned, and this ore is widely distributed. All the deposits are argentiferous, and some auriferous; but they have not as yet been worked for lead. Among the localities may be named Great Barrier Island, the Thames, and Te Aroha, Auckland; Wangapeka and Collingwood in Nelson; and Mount Rangitoto, and other places on the west coast of the South Island. Other ores are known, but they are not commercially valuable. Cerussite is not found.

(3) *Mercury.*—In a country where gold-mining is carried on to a great extent there is always a plentiful demand for mercury; and it is to be regretted that although this metal has been found in New Zealand, both native and combined, the quantities discovered have been too small to be worked.

Metallic mercury occurs at Waipori in Otago, and at the Ohaewai Springs, near the Bay of Islands, Auckland. Cinnabar or sulphide, has been found in the alluvial deposits of the Obelisk Range, Potter's Gully, Dunstan, Serpentine Valley, all in Otago, and also at the Ohaewai Springs, and on the Puhipuhi field; and the writer has been shown a specimen said to have been brought from the upper waters of the Buller River.

(4) *Barium.*—Barytes is known to exist in many places, but not as a reef. The Thames gold-field in Auckland, Akiteo in Wellington, Opotiki, Makara, Herbertville, and Waikouaiti are all mentioned. Witherite has also been noted from the Thames.

(5) *Bismuth.*—The occurrence of this metal in the auriferous rocks of the Owen, Nelson, was discovered by Mr. Skey in February, 1887. Subsequent investigations proved that it exists in the native state as a metal, and quite independently of the gold.

(6) *Arsenic.*—Mispickel has been mentioned, and the native metal has been found in the Coromandel district, Auckland. It has not been utilized.

(7) *Nickel.*—Until nearly the end of 1886, nickel was known to occur only as a constituent of troilites and pyrrhotines, and in a few other cases; but in October, 1886, Mr. Macfarlane, the gold-fields' warden at Jackson's Bay, forwarded a collection of ores, which, on examination by Mr. Skey, proved to be nickeliferous. Among them was an exceedingly interesting mineral, which was supposed by the diggers to be impure platina, but which proved to have a composition as follows:—

	Per Cent.
Nickel	67·63
Cobalt	·70
Iron	31·02
Sulphur	·22
Silica	·43
	100·00

and a formula of 2 Ni + Fe. This is a very unusually high percentage of nickel, the largest previously known being 51·22 per cent., which is present in Oktibehite, a mineral of meteoric origin. The ore under consideration is of terrestrial origin, and has been named Awaruite, after

the Awarua River, where it is found, the associated rock being serpentine. For a very detailed and interesting account of this mineral see a paper by Prof. Ulrich, in the *Quarterly Journal of the Geological Society.**

As mentioned under "Iron," pyrrhotine was found in 1876, near Mount Cook, and it has in addition been discovered at the Paringa River, Westland, at Dusky Sound, and Collingwood, where it yields 2·98 per cent. of nickel.

(8) *Diatomaceous Earth.*—A large deposit of this material occurs near Oamaru, Otago, and though of surpassing interest to the microscopist has not been worked for commercial purposes. It has also been found in Marlborough, and in the North Island at Foxton.

(9) *Asbestos.*—Samples of asbestos have been brought from Milford Sound, and also from Collingwood and the Dun Mountain, but none of it is of first-class quality.

(10) *Precious Stones and Gems.*—Much excitement has frequently been caused by supposed discoveries of diamonds, but unfortunately no authentic instance has occurred.

The following is a list of most of the gems and semi-gems which have been found in the colony:—

Amethyst.—Raikaia Gorge, Canterbury.

Bloodstones (inferior).—Canterbury and Herbertville.

Corundum.—A large sapphire was forwarded from Collingwood, Nelson, but it was so fissured as to be useless as a gem. Some stones forwarded from Rimu, Hokitika, by Mr. W. Goodlett in March, 1892, were determined by Prof. Ulrich as true Oriental rubies.

Emeralds have been determined in a pyrrhotiniferous quartz from Dusky Sound, Otago.

Gahnite has been found at Stewart Island.

Garnets are very plentiful in the gold wash of the South Island.

Jasper, Carnelian, and Agates.—At many places.

Jasper Opal.—Portobello, Otago Harbour.

Nephrite or jade is found *in situ* only at Milford Sound. Boulders are found plentifully in the auriferous wash of the west coast, South Island.

Topaz has been found at Chatto Creek, Arrow River, Waipori, all in Otago.

Zircons are recorded as having been discovered at Timbrills Gully, and in biotite rock from Doubtful Inlet, Otago.

* Vol. xlvi., 1890, page 619.

Compared with the export of gold the value of the minerals mentioned in this portion of the paper is no doubt small, but the list given serves to show that the resources of the colony are at any rate exceedingly varied. Surprise may be felt that the result in so many cases has been nothing but disappointment, and the reason is naturally sought. It is, the writer ventures to think, to be found in several directions. In the first place, it is not easy in a new country in making any unusual departure in mining to obtain all the skilled labour and direction which are so necessary. Those investors who have been accustomed to gold-mining ventures have learned to expect an immediate return, and any delay—whether owing to difficulties in treatment, scarcity of market, or any other cause—may check the regrettable excitement so often attendant on such enterprises, and land the company in liquidation.

New Zealand is a recently settled and sparsely populated country. Among its inhabitants are men whose lives have seen many changes, and whose occupations have been various. Concurrently with other employments they may have taken up, without any previous knowledge, the pursuit of mining, and may doubtless have not only ruined themselves financially, but cast the shadow of failure on what might have been, if rightly conducted, a successful speculation.

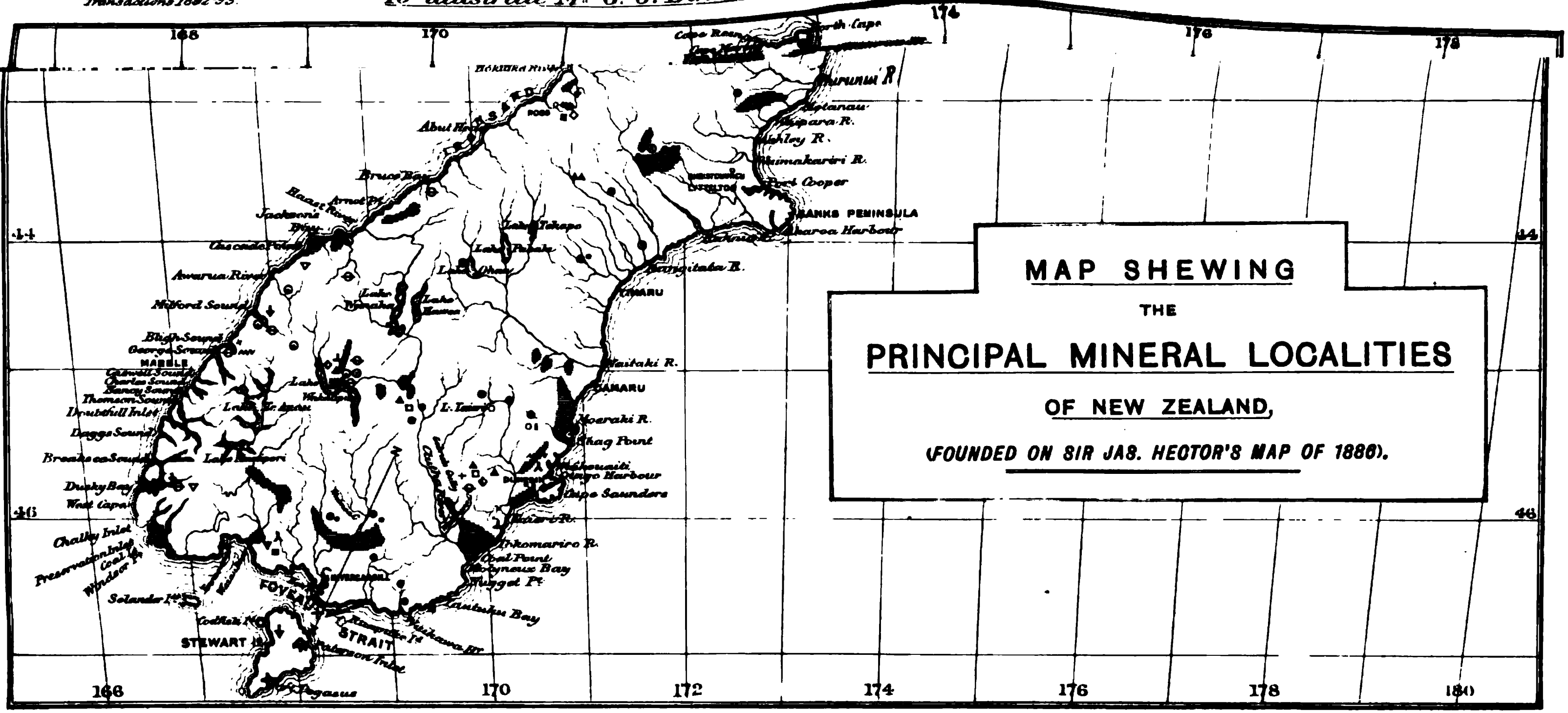
Again, money is scarce, calls are frequent, and unscrupulous promoters are not entirely unknown.

The country is rough and wages are high, as is also the price of provisions. Small wonder therefore that though the stores of mineral riches are plentiful and varied, many disastrous failures have already been chronicled. For the large population which the colony is adapted to, and which it must sooner or later support, the minerals placed in its mountains and valleys must prove a rich inheritance.

APPENDIX.—TABLE SHOWING THE TOTAL QUANTITY OF MINERAL ORES (THE PRODUCT OF MINES, OTHER THAN GOLD, COAL, AND KAURI GUM) EXPORTED FROM THE COLONY UP TO DECEMBER 31ST, 1890.

Year	Silver		Copper Ore		Chromium Ore		Antimony Ore		Manganese Ore		Hematite Ore		Mixed Mineral Ores		Totals		
	Oz.	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Oz.	Tons	Value
		£		£		£		£		£		£		£			£
1858	...	...	351	3,000	3	25	...	...	...	...	...					[illegible]	[illegible]
1859	...	...	245	2,605	8	120	...	...	...	...		...				[illegible]	[illegible]
1860	...	...	137	1,590	116	1,140	...	...	...	...			...			[illegible]	[illegible]
1861	...	...	110	1,300	52	520	...	...	...							[illegible]	[illegible]
1862	...	...	51	1,024	3,843	24,719	...	...	...							[illegible]	[illegible]
1863	...	...	...	...	595	4,318	...	...	...	...	...					[illegible]	[illegible]
1864	...	...	...	...	768	4,910	...	...	...							[illegible]	[illegible]
1865	...	...	...	...	...	...	...	...	...	...	...						
1866	...	...	...	...	281	1,815	...		...		...					[illegible]	[illegible]
1867	...	...	246	2,700	...	...	...	...	...		...		...			[illegible]	[illegible]
1868	...	...	84	977	...	...	...	...	...		...					[illegible]	[illegible]
1869	11,063	2,993	...	...	...	...	...	...	...	...	...				11,063		[illegible]
1870	37,123	11,380	7	120	...	...	...	...	...	...	...				[illegible]	7	[illegible]
1871	80,272	23,145	...	...	...	...	...	...	...	...	...				[illegible]		[illegible]
1872	37,064	9,910	...	...	...	...	...	...	...						[illegible]		[illegible]
1873	36,187	9,850	...	...	...	...	...	...			...				[illegible]		[illegible]
1874	40,566	10,380	...	...	...	...	...		...		...				[illegible]		[illegible]
1875	29,085	7,569	...	...	...	...	...	...	...	...					[illegible]		[illegible]
1876	12,683	3,171	...	...	...	...	...	...	...	...			8,180	14,844	[illegible]	8,180	[illegible]
1877	33,893	7,556	...	...	...	...	...	...	...	...	...		2,000	9,004	[illegible]	[illegible]	[illegible]
1878	23,019	5,755	6	115	...	...	4	102	2,516	10,416			9	8	[illegible]	[illegible]	[illegible]
1879	20,645	4,512	55	1,105	...	...	...	...	2,140	8,988					[illegible]	[illegible]	[illegible]
1880	20,005	4,500	...	...	...	...	60	612	2,011	10,120		...	2,074	11,005	[illegible]	[illegible]	[illegible]
1881	18,885	4,236	5	36	...	...	2	24	1,271	8,268			1,056	4,008	[illegible]	[illegible]	[illegible]
1882	5,694	1,286	9	41	...	...	30	900	2,181	6,000	...		2,784	8,607	[illegible]	[illegible]	[illegible]
1883	16,826	3,785	46	678	...	...	31	804	384	1,155	½	12	22	110	[illegible]	[illegible]	[illegible]
1884	24,914	5,125	20	106	...	...	...	...	318	809		...			24,914	338	[illegible]
1885	16,624	3,169	...	...	...	...	666	5,289	602	1,716	50½	208	114	995	16,624	1,432½	11,870
1886	12,108	2,946	20	390	...	...	62	1,784	324½	1,816	...	...	145	1,846	12,108	555½	8,282
1887	20,809	3,453	...	...	...	...	184	3,989	305	895	...	...	144	4,142	20,809	583	12,479
1888	403	71	2	75	...	...	376	6,246	1,085	2,404	...	...	162	2,955	403	1,625	11,751
1889	24,105	4,043	...	...	...	...	493	5,319	1,080	2,569	...	...	199	9,985	24,105	1,772	21,916
1890	32,637	6,162	...	...	...	...	515	11,121	482	1,004	1½	5	19	278	32,637	1,017½	18,565
Totals	554,610	134,997	1,894	17,862	5,666	37,367	2,378	36,190	15,303½	51,291	52½	225	14,066	69,035	554,610	38,855	346,967

To illustrate Mr. G. J. Binns' Paper on "Mining in New Zealand."



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APPENDIX.—TABLE SHOWING THE TOTAL QUANTITY OF MINERAL ORES (THE PRODUCT OF MINES, OTHER THAN GOLD, COAL, AND KAURI GUM) EXPORTED FROM THE COLONY UP TO DECEMBER 31ST, 1890.

Year.	Silver.		Copper Ore.		Chromium Ore.		Antimony Ore.		Manganese Ore.		Hæmatite Ore.		Mixed Mineral Ores.		Totals.		
	Oz.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Oz.	Tons.	Value
		£		£		£		£		£		£		£			£
1858	...	...	351	5,000	3	25	...	...	...	...	...	...	...	...	...	354	5,025
1859	...	...	245	2,605	8	120	...	...	...	...	...	...	...	...	...	253	2,725
1860	...	...	137	1,590	116	1,440	...	...	...	...	...	...	...	...	...	253	3,030
1861	...	...	110	1,300	52	520	...	...	...	...	...	...	...	...	...	162	1,820
1862	...	...	51	1,024	3,843	24,719	...	...	...	...	...	...	...	...	...	3,894	25,743
1863	...	...	...	...	595	4,318	...	...	...	...	...	...	...	...	...	595	4,318
1864	...	...	...	...	768	4,910	...	...	...	...	...	...	...	...	...	768	4,910
1865	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1866	...	...	...	...	281	1,315	...	...	...	...	...	...	...	...	...	281	1,315
1867	...	...	246	2,700	...	...	...	...	...	...	...	...	...	...	...	246	2,700
1868	...	...	84	977	...	...	...	...	...	...	...	...	...	...	...	84	977
1869	11,063	2,993	...	...	...	...	...	...	...	...	...	...	...	...	11,063	...	2,993
1870	37,123	11,380	7	120	...	...	...	...	...	...	...	...	...	...	37,123	7	11,500
1871	80,272	23,145	...	...	...	...	...	...	...	...	...	...	...	...	80,272	...	23,145
1872	37,064	9,910	...	...	...	...	...	...	...	...	...	...	...	...	37,064	...	9,910
1873	36,187	9,850	...	...	...	...	...	...	...	...	...	...	...	...	36,187	...	9,850
1874	40,566	10,380	...	...	...	...	...	...	...	...	...	...	...	...	40,566	...	10,380
1875	29,085	7,569	...	...	...	...	...	...	...	...	...	...	...	...	29,085	...	7,569
1876	12,683	3,171	...	...	...	...	...	...	...	...	...	...	3,180	14,824	12,683	3,180	17,995
1877	33,893	7,556	...	...	...	...	...	...	...	...	...	...	2,366	9,664	33,893	2,366	17,220
1878	23,019	5,755	6	115	...	...	4	102	2,516	10,416	...	...	2	8	23,019	2,528	16,396
1879	20,645	4,512	55	1,105	...	...	...	...	2,140	8,338	...	...	...	...	20,645	2,195	13,955
1880	20,005	4,500	...	...	...	...	60	612	2,611	10,423	...	...	2,674	11,335	20,005	5,345	26,870
1881	18,885	4,236	5	36	...	...	2	24	1,271	3,283	...	...	1,955	4,303	18,885	3,233	11,882
1882	5,694	1,286	9	41	...	...	30	900	2,181	6,963	...	...	2,784	8,597	5,694	5,004	17,787
1883	16,826	3,785	46	678	...	...	31	804	384	1,155	½	12	22	110	16,826	483½	6,544
1884	24,914	5,125	20	106	...	...	...	...	318	809	...	...	...	...	24,914	338	6,040
1885	16,624	3,169	...	...	...	...	666	5,289	602	1,716	50½	208	114	993	16,624	1,432½	11,375
1886	12,108	2,946	20	390	...	...	62	1,784	328½	1,316	...	...	445	1,846	12,108	855½	8,282
1887	20,809	3,453	...	...	...	...	134	3,989	305	895	...	...	144	4,142	20,809	583	12,479
1888	403	71	2	75	...	...	376	6,246	1,085	2,404	...	...	162	2,955	403	1,625	11,751
1889	24,105	4,043	...	...	...	...	493	5,319	1,080	2,569	...	...	199	9,985	24,105	1,772	21,916
1890	32,637	6,162	...	...	...	...	515	11,121	482	1,004	1½	5	19	273	32,637	1,017½	18,565
Totals	554,610	134,997	1,394	17,862	5,666	37,367	2,373	36,190	15,303½	51,291	52½	225	14,066	69,035	554,610	38,855	346,967

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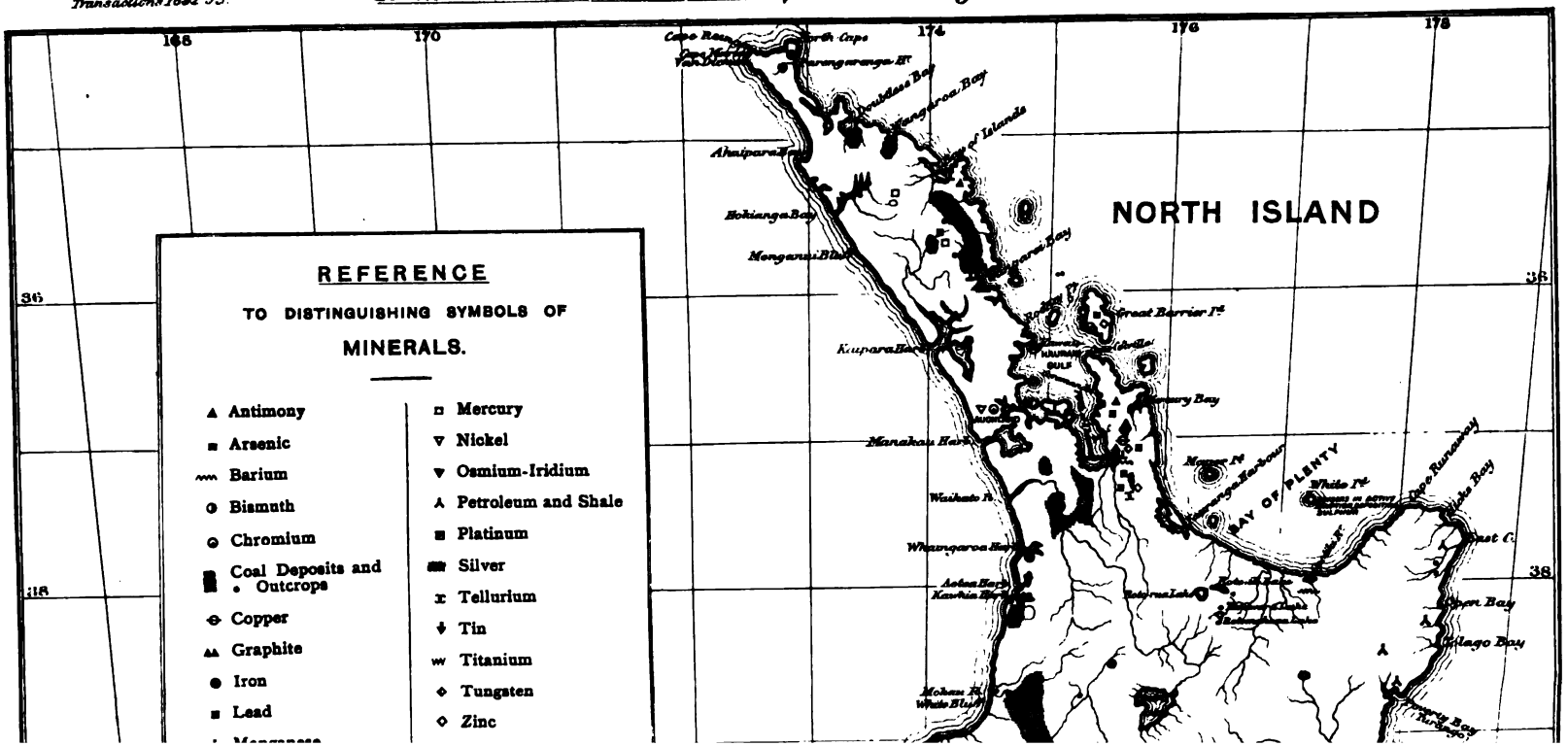


THE COAL-FIELDS SOUTH OF SYDNEY, NEW SOUTH WALES.

By JAMES R. M. ROBERTSON.

Introduction.

At the meeting of the Federated Institution of Mining Engineers, held in London, in May, 1891, Messrs. George Blake Walker and S. Herbert Cox read interesting papers on the coal-fields of Australasia, in which a large amount of information was given. Both papers being of a somewhat general and discursive character, it was suggested that it would be of interest were the writer to give some details on one or other of the coal-fields referred to.

As the writer has recently dealt with the Newcastle Coal-field (New South Wales) in a communication to a local institute, he proposes to give a short description of the coal-fields south of Sydney, and in doing so he will, as much as possible, avoid the ground traversed by Mr. Walker in his admirable notes on Australian coal-mining.

The writer attaches a map, Fig. 1, Plate VIII., showing the southern Coal-measures of New South Wales. These maps are to some extent works of fiction, and the writer is inclined to alter the confines of the Coal-measures to the south and west of Sydney, as shown on Mr. Walker's map,* so as to represent the actual margins of the Carboniferous rocks; while the anticlinal as shown in Mr. Walker's map is illusory, no such curvature exists.

The Illawarra, southern and western coal-fields are a continuation of the same beds. The southern coal-field embraces the Carboniferous areas south of Sydney, including those traversed by the Great Southern Railway.

The Illawarra coal-field fringes the coast-line from Coalcliff to Kiama, a distance of 35 miles, and extending west of the line of sea-cliffs, and northwards for other 35 miles under the broken country composed of Hawkesbury Sandstones that intervenes between Coalcliff and Sydney Harbour.

The western coal-field is a continuation of the same beds under the elevated ranges known as the Blue Mountains.

The southern coal-field, on account of its elevation, stretches farther south than the same measures in the Illawarra district.

* *Trans. Fed. Inst.*, vol. ii., plate xxvi.

The area of these coal-fields is practically that covered by the Hawkesbury Sandstones and shales, but for reasons that will hereafter be referred to, any computations of quantities based upon the actual area of the Coal-measures are misleading, and this the writer fears is the character of the estimates of quantities contained in the colonial Blue Books. In the writer's opinion they are of no value as indicative of the actual coal resources of the colony.

The Hawkesbury Sandstones.

The Hawkesbury Sandstones overlie the Coal-measures and have preserved and protected them from denudation. This is a formation peculiar to Australia or probably the East. It is unfossiliferous and its geological age is a matter of conjecture. Probably it may be coeval with the Permian of Europe. This, in turn, is covered by black or grey aluminous soft schists mixed with siliceous layers called the Wianamatta shales.

The Hawkesbury rocks consist of coarse unbedded or irregularly bedded masses of gritty sand containing pebbles, and occasionally small nodules of waterworn stones of volcanic origin. For several hundred feet from their base these beds are composed of coarse drifts; but higher up they are enclosed in convoluted kernels or shells of silica firmly cemented with ferruginous matter. Still higher up oblique and twisted bedding occurs, and lastly these are covered by the evenly-disposed beds of mudstone or clayslate referred to.

The whole formation unmistakably points to a slow depression of land extending through long periods of time, and to a deposition of sand in shallow water subject to variable and rapid currents. This great formation represents the waste by denudation of pre-existing rocks, and lastly, the shales reposing upon the sand in thin and even layers, appear to have been finely-ground detritus or mud carried into lagoons or tranquil waters and there deposited layer above layer in even and undisturbed beds. The writer has seen no evidences in Australian Coal-measures of glaciation as has been suggested by Mr. Walker, or any boulders of a size that could not have been rounded by the agency of currents and rapid streams.

The thickness of the Hawkesbury rocks has not been ascertained, no boring having been commenced in the overlying shales that has penetrated the sandstones.

While the top of the sandstones has been defined as above, there is no evidence, so far as the writer is aware, of any stratified deposits overlying these sandstones and shales.

The coal-seams underlying these coarse, loosely-aggregated sandstones between the Coal-measures and Hawkesbury rocks are overlain by strata not materially dissimilar to what the writer has described; they contain coarse sandstones and grits; siliceous schists a few feet in thickness; and a green pebbly conglomerate so persistent as to afford a reliable horizon amid such a vast mass of nondescript and variable strata, consisting of felstone pebbles, felspar, trap and quartz, all waterworn, in a siliceous matrix, evidently the detritus of distant granite and volcanic rocks carried by rapidly moving water, and these are succeeded by beds of red ferruginous aluminous shales or bind known as "chocolate shales," or termed "ironstones" by some irrepressible enthusiasts, when in the deeper measures bind of a purple colour is met with.

The thickness of the measures between the Hawkesbury Sandstones and the upper coal-seam varies according to the district between 350 and 1,600 feet.

In the western and southern coal-fields a remarkable thinning of the measures is perceptible, and the distance between the "chocolate shales" and the upper coal is correspondingly slight. In the Illawarra mountains the shales are very thin (a few feet), and are found about 250 feet above the upper coal, while towards the north-north-west (or dip of the strata towards Sydney), these shales thicken out to several hundreds of feet, and are separated from the coal by about 200 feet near Wollongong and 300 feet at Katoomba in the western district to about 1,500 feet, as at Sydney Harbour. The chocolate shales themselves thicken in the deep measures near Sydney, whereas in the Blue Mountains their thickness varies between 2 and 12 feet; at Sydney Harbour they are 200 feet thick, and at Narrabeen 12 miles to the north, they measure 600 feet.

At Holt Sutherland, 15 miles south of Sydney, coal was struck at a depth of 2,460 feet, the sandstones being 653½ feet thick, and separated from the Coal-measures by 1,573¼ feet of shales, sandstones and conglomerate.

The writer sees no valid reason for limiting the Hawkesbury Sandstones to the horizon of the red shales, as they lie conformably upon the shales; in fact there are no unconformable strata between the upper coal-seams and the base of the Hawkesbury Sandstones. The strata overlying the coal are similar in character to the Hawkesbury Sandstone, and so far as the writer can see are of the same age. In the writer's opinion it would not be wrong to say that the Hawkesbury Sandstones include the strata overlying the Coal-measures. Sandstones identical in character form the mountain-ranges at the head of the Simmoongin and Strop Rivers in

Sarawâk, and overlie coal-seams similar to those worked at Newcastle in this colony. The writer looks upon these as contemporaneous with the Hawkesbury Sandstones.

The Hawkesbury Sandstones have in times past formed a vast plain in continuation of the plateau of Palæozoic rocks, extending from Goulburn to the south and west, and abutting against the mountain chain that runs north and south, forming the western margin of the Blue Mountains.

The Blue Mountains are remarkable for deep valleys bounded by ramparts of bold precipitous crags, and for a mysterious blue transparency of the atmosphere that gives the irregular gorges their name. These valleys, such as the Kanimbla, Jamieson, and the Grose, descending to a depth of 2,000 feet, have been eroded through the Coal-measures into the Devonian or still older rocks on which in the western district the Coal-measures rest. These grand and solemn cañons, as well as the arms and bays of the natural harbours of Sydney, Broken Bay, Botany, and Port Hacking, matchless in their beauty and irregular outline, have been solely formed by the operation of natural forces, of climate and time, extending through cycles of years, probably under physical conditions different from those that now prevail, aided in recent geological time by the stupendous volcanic agencies to which reference will be made.

Nearly every depression, gully, glen, or ravine has been formed near or over or along the course of a dislocation of the strata, or more commonly of a recent dolerite dyke. The rapid decay of these recent basalts on exposure to the air or elements has been the principal cause of the superb tropical foliage and grandeur of the Illawarra ravines, as well as the richness of the grassy and fertile character of the soil of this the garden of New South Wales.

The age of the Hawkesbury Sandstones, resting as they do conformably on the Carboniferous series is uncertain and undetermined, as they contain no fossil evidences of a definite or distinctive character by which their age might be determined or approximated. The writer is disposed to consider the Coal-measures as of Triassic age: the dirt bands that are interlaminated with some of the coal-seams; the want of character of the dividing strata; the absence of index horizons with distinctive fossils and lithological evidence; the extreme variations in the coal-seams and the dividing strata; are altogether different from what one observes in the Carboniferous measures of Great Britain or America. There are in fact no points of similarity between the Coal-measures under review and those of Europe.

The Illawarra Coal-measures.

In the Wollongong district of Illawarra the coal-seams are most numerous and the measures the thickest. This district contains seven seams of coal. From the presence of stone bands and the inferior quality of the coal only one of these seams, the upper, is at present of any commercial value, and only two are ever likely to be generally worked. The variations of these will be presently referred to.

At Wollongong, in Illawarra, the Coal-measures attain a thickness of 700 feet; but 30 miles to the west, near Moss Vale, they only measure about 150 feet, and comprise three coal-seams, one of which is too thin to work, while the other two, although thick, are of inferior or unmarketable quality. From Moss Vale the measures gradually increase in thickness to the north and east; in the western district they measure about 350 feet.

The individual coal-seams are not of equal quality or thickness in the same or several districts. The uncertainty and variations in the thickness of the beds is a characteristic feature of the series, but although the seams may thicken or thin, or be changed by natural agencies, their identity can in a general way be determined by chemical analysis, and to a less extent by the character of the strata in which they are found.

On the east of the southern coal-field the restless waters of the Pacific lave the beetling crags of these sandstones for 30 miles south of Sydney, broken only by the irregular arms of the sea known as Botany Bay and Port Hacking, indentations that bifurcate and carry tortuous reaches of salt water far inland among rugged ravines instinct with beauty. At Coalcliff the sandstone ranges, 1,300 feet in height, gradually recede from the sea coast, a plateau of Carboniferous rocks intervening, covered by rich soils and verdant pasture. The ravines are choked with a dense growth of ferns, palms, creepers, and flowering shrubs. The mountain tops are covered with stunted, gnarled, and melancholy trees. For 9 miles the mountain ranges are within a mile or so of the coast, but at Bulli the breadth of the intervening zone continues to increase until at Wollongong the line of cliffs is 3 miles distant. At Wollongong they form a prominent bluff, Mount Keira, 1,500 feet above the sea, and at this point they recede 4 miles to the west, and, bending south, the bold and picturesque landmark of Mount Kembla rises to a height of 1,800 feet, covered by dense, dark, luxuriant foliage. Mount Kembla is separated from the main range by a depression. Here again the ranges recede a few miles to the west, and forming a great semicircle approach the sea at the basaltic promontory of Kiama.

The Hawkesbury Sandstones between Mount Kembla and Kiama

attain an elevation of 2,000 feet, and gradually rise to the west. Twelve miles south of Kiama the noble harbour of Jervis Bay has been carved out of Lower Carboniferous rocks. The general physical features of these ranges is an irregular line of bold, reddish-coloured perpendicular cliffs, several hundreds of feet in height, with steep slopes composed of fallen rocks and *débris* covered with a dense vegetation.

In front of Mount Kembla, and separated from the ocean by a low and narrow strip of land, is Lake Illawarra, which has been worn out of the rocks underlying the coal-seams, and with its islets and deep indentations lends a peculiar charm to one of the loveliest districts in Australia.

Illawarra really embraces the rich soils, farming and grazing lands situated between the ranges and the coast line, between Kiama in the south and Coalcliff on the north. In times past this stupendous deposit of sandstone must have extended some distance out to sea; under the influence of a coast slowly sinking, aided by volcanic forces that in parts have shattered and induced remarkable decay, the cliffs lashed by the waves are crumbling away, the constant southerly current is laden with sand, and the sand dunes and beaches are but the evidences of the destruction that the forces of nature, ceaseless in their operations, work upon the everlasting hills.

At Coalcliff, the upper coal-seam is seen cropping out in the perpendicular cliff about 18 feet above the sea-level. The coal-seam has a sandstone roof and floor. In an indentation a few yards north it is thrown down by a 30 feet fault, while a few hundred yards south it is thrown up by a 100 feet riser fault, in consequence of which the three lower seams appear in the cliffs. The upper coal from this point gradually rises higher and higher on the slopes of the ranges until at Wollongong it is 640 feet, and at Mount Kembla 800 feet above sea-level. North of Wollongong the lowest coal-seams of the series underlie the level land at the base of the ranges, but at Mount Kembla and to the south the whole of the coal-seams can be traced outcropping on the mountain side above the level of the valleys.

On the general map, Fig. 1, Plate VIII., the respective positions of the several collieries are shown. At Mount Kembla the upper coal thins, and a few miles south it is only a few inches in thickness, and is full of little cavities, probably due to the decay of casts of Sporangia; it is indeed little better than bituminous shale, but the lower seams are persistent and rather improve in quality at Jamberoo, near Kiama, but their continuity has been greatly disturbed by intrusive dykes.

The upper coal-seam is really the only marketable one of the series,

and its area of distribution is from Mount Kembla northwards. The quality remaining the same, the thickness of the seam is variable. Towards the southern boundary of Mount Kembla colliery, this seam is only 2 feet 6 inches thick, and increases rapidly to the north, the increase appearing in the bottom portion of the coal. In half a mile, the thickness varies between 4 feet and 6 feet of clean, hard coal; northwards it increases to 7 feet 6 inches. The seam continues of this thickness under Great Wollongong, Mount Keira, Mount Pleasant, and Corrimal. Under the large colliery of South Bulli, north of the east-and-west dyke, it increases in some districts to 11 feet; it is 7 feet 6 inches and 8 feet under Wonoona and Bulli, but north of the faulted zone that intersects the last-named colliery the seam gradually thins. Under North Illawarra, No. 2 tunnel, it varies between 3 and 4 feet, and continues about 3 feet 6 inches thick to South Clifton, where it measures 4 feet 7 inches; and in Coalcliff it is 5 to 6 feet, increasing to the north, and in the Metropolitan colliery and Coalcliff freehold; across a suppositious basalt zone it is 11 feet. With the increase in thickness a number of "horses," really "rises" or "rolls" or "crumplings," of the floor of irregular shape are found in the southern division. These seldom rise more than 4 feet from the floor, and are rarely persistent for any length. The floor appears to be dotted over with them; they are composed of dark bind or blae, and commencing like a wedge they increase in height and width, and die off in the same manner. Strange to say, north of Bulli, few rolls in the floor are met with, and in the southern division of Mount Kembla colliery, where the coal begins to decrease in thickness, there is also an absence of them. In the district north of Mount Kembla and south of Bulli, where the coal-seam thickens, they appear and continue throughout the thick-coal pits of Great Wollongong, Mount Keira, Mount Pleasant, Corrimal, South Bulli, Bellambi and Bulli; they are practically absent in the thin-coal pits north of this; showing, however, that the thickness has no influence, and that they are attributable to local causes. No rolls exist in the Metropolitan colliery, where the seam is 11 feet thick. On account of the high rate of wages paid to colonial coal-miners, it is inexpedient to cross these curious yet awkward occurrences with the bords. As a rule therefore the winning headings in the collieries where these exist are laid off so as to cross these, while the bords (broken off 2 yards wide) are widened out to 8 yards between, and are driven parallel, leaving the rolls for pillars. Under these circumstances it is impossible to carry on mining operatons with exactitude, and the occurrence of rolls adds about 2d. per ton to the cost of pro-

duction. These rolls have a general trend north-west and south-east 25 degs., and have evidently been laid down by the agency of currents prior to the deposition of the coal-seams. They seldom or never affect the roof, but they render the systematic laying out of a coal-mine almost impossible. A roll is illustrated in Fig. 2, Plate IX. The incidence of dolerite in the three upper seams is shown in sections (Figs. 3 to 11, Plate IX.).

The coal-beds dip to the north of west, varying a few degrees in the various collieries, which are shown on Fig. 1, Plate VIII. The pitch of the seam varies between 1 in 20 near to the outcrop to 1 in 50, farther under the ranges. At the Metropolitan colliery, the pitch of the seam is 1 in 6 to 1 in 9, but this is probably owing to its proximity to a faulted zone of country.

The coal-seams give off little water, and, as a rule, no marsh gas. Occasionally, however, in virgin ground, a little gas is in some of the collieries given off in the vicinity of dolerite dykes. This is the character of the Illawarra collieries; but in the new winning of the Metropolitan colliery, 1,080 feet deep, a sufficiently large amount of gas was given off to necessitate the use of safety-lamps. This gas possesses peculiar properties; it lies on the thill or floor, and emanating from the rise workings, it flows like a liquid to the lower workings, which it fills from the floor upwards. Analysed by Dr. Helms, of Sydney, this gas has the following composition:—

	Per Cent.
Carbonic acid gas	23·484
Marsh gas	14·626
Carbonic oxide	4·712
Hydrogen	·428
Oxygen	11·160
Nitrogen	45·590
	100·000

Omitting the oxygen and nitrogen, which would form a certain part of the air equal to 42·084, there would remain:—

	Per Cent.
Carbonic acid gas	50·22
Marsh gas	31·28
Carbonic oxide	10·88
Hydrogen	·92
Nitrogen	7·50
	100·80

The specific gravity of this gas is 1·16. It is exceedingly inflammable, and readily fires within the lamp. It evidently exists in the coal-seam under considerable tension, and bursts out portions of the seam whenever

it is touched with a pick. The latter gas is swept out and controlled by the enormous ventilating current that is maintained at that beautifully fitted colliery. Gas of a similar character, but occurring in insignificant quantities, has been detected in one or two of the Illawarra collieries.

The upper coal-seam is a steam coal, and is the only one of any commercial value in the series. With the exception of a very small quantity of the Four-feet seam worked at Bulli, no other coal-seam is worked in the district.

The seam has some peculiar features. Lithologically it consists of alternate thin layers of bright and dull highly-bituminous coal; and among these occur almost imperceptible lines of "mother of coal." The bituminous layers adhere to the others, and break readily, showing oblique or irregular rhombic cleavages or crystals. At the Metropolitan and Mount Kembla collieries the bituminous layers are not pronounced, hence the coal from these collieries is harder, and better able to resist transit. Although the layers of deposition are clearly defined, the coal breaks or cleaves across them in pyramids or prisms, probably due to the permeation of heated gases from the enclosing porous rocks. This peculiar cleavage cannot be due to the depth, as the shallowest collieries contain coal that has evidently been most subjected to heat *in situ;* moreover, the coal bursts out of the face or from pillars in the form of irregular columns or prisms. In some of the collieries where the coal is rather tender, the lumps are apt to break into thin scales; being dry and friable, it yields quantities of fine pulverulent dust of a most penetrating description.

In the majority of collieries the soakage from the hill slopes keeps the roads damp or moist, but in others, notably Mount Keira, Bulli, and Metropolitan, no water exudes, and the roads are disagreeably dusty. It was to the dusty character of Bulli colliery that the disastrous effects of the recent explosion are mainly to be attributed; the flame from a small quantity of gas ignited the dust, and was prolonged through the nearer workings.

With the exception of the Metropolitan colliery, the whole of the Illawarra collieries work by means of adits that, tapping the seam on the steep slopes of the ranges, follow it to the dip. These collieries produce large daily outputs under rather difficult conditions. The adits, with two exceptions, in the case of the Corrimal colliery recently opened, have been begun on the almost perpendicular sides of the mountain, just under the cliffs, and in some cases barely sufficient room can be obtained to place the necessary hauling and other machinery.

From the screens, the railway wagons are run down steep inclines, with gradients averaging 1 in 2½, to the termini of the private lines that connect on to the Government railway, or to private jetties, where the contents are tipped into steam colliers, carrying from 400 to 2,500 tons. At some of these jetties 400 tons an hour can be put into ships' holds.

The skips contain on an average 12 to 15 cwts. of large coal; they are fitted with 12 inches steel wheels, and they tare about 4¾ cwts. The main roads are carefully laid with heavy rails, straightened and fish-plated. The haulage is, as a rule, by main-and-tail rope. Trains of 50 to 60 skips are run at a speed of about 12 miles an hour.

At the South Bulli and Metropolitan collieries endless-rope haulage has been introduced, delivering single skips; and the attachments or clips have been devised to meet the special circumstances of the haulage. Electric signals are in use in Metropolitan, South Bulli, and Mount Kembla collieries. At the latter colliery, Priestman oil engines have been introduced for dealing with the mine water, and are doing excellent work. This system or of pumps actuated by electricity will supersede the use of those driven by compressed air, that have been for some years in operation.

The upper coal-seam has the following composition, which may be taken as a fair average of the existing Illawarra collieries:—

	Per Cent.
Moisture	0·40
Carbon	79·66
Hydrogen	5·36
Oxygen	3·68
Sulphur	0·49
Nitrogen	0·67
Ash	9·74
	100·00

By experiments with the calorimeter it was found that 1 lb. of this coal would convert 13·21 lbs. of water into steam.

The analysis of its ash is as follows:—

	Per Cent.
Silica...	52·57
Alumina	43·55
Iron sesquioxide	0·95
Manganese	trace.
Lime...	1·35
Magnesia	0·60
Potash	0·15
Soda	0·27
Phosphoric acid	0·17
Sulphuric acid	0·79
	100·40

The assay of this seam does not to a material extent vary in the different collieries, and thus forms a valuable means of determining the identity of the coal-seam at distant points. The same remark applies to the principal coal-seams in the different districts of the colony.

The above analysis shows that, although the ash is abundant compared with the finest British coals, yet the high calorific value and the small proportion of sulphur makes this a steam coal of great value, and as such it is rapidly gaining ground in the very markets where the demand for the more bituminous coal of Newcastle is decreasing. All the lines of ocean and colonial steamers, the men-of-war, and the majority of the railways in this colony and on the west coast of America use this coal; it gives off a fierce heat, with a good draught, and with careful stoking produces very little smoke; it stows into less space, and is at the same price a superior and much cheaper fuel, and, being non-flaming, is better adapted for high-pressure or any boiler than the more bituminous and more valuable gas-producing coal of Newcastle. The analysis of the ashes of these two coal-seams occurring in different districts is dissimilar; the ash of the Illawarra upper coal contains less phosphoric acid, viz., 0·22 against 1·5 per cent. as in the Newcastle seam; the ash of the Illawarra coal contains rather more alumina and silica but less ferric oxide than that of Newcastle, consequently it does not clinker, while in quantity it is more than double that of the Borehole seam of Newcastle. The lowest seam in the southern and western district "the Lithgow" is just as dissimilar from the Borehole seam of Newcastle as the upper coal of the southern district described.

The roof of the seam is as a rule remarkably good and firm, and if worked in 5 yards bords would require little timber.

The coal-seam contains as a rule no stone bands or pyrites. It is easily worked; the district rates for coal-seams above 5 feet being 2s. 4d. for large coal passed over bars ¾ inch apart and filled into skips.

In consequence of the increase in the number of large steamers visiting the colonies, and the introduction of engineers of superior knowledge and erudition, and of boilers where a higher steam pressure is necessary, the necessity for a steam coal has brought the excellent qualities of the Illawarra upper coal into repute. From the low percentage of hygroscopic water it contains, and consequently the unreadiness of the coal to absorb oxygen, there is no risk of spontaneous combustion when stowed into bunkers or cargoes. The absence of sulphur is also a point of great importance in its favour.

LABOUR.

In this district the owners have so far successfully resisted every attempt of the men to introduce the pernicious customs predominating in the Newcastle district, customs that unless rectified must entangle all the collieries there in complications, and increase the cost of production to an extent that may make coal-mining, if possible, unremunerative. In the Newcastle district the men virtually manage the mines in so far as they regulate the amount to be produced by each man or district, and this amount is based on the capabilities of the inferior men. They order home men who have slightly exceeded their allotted output; they impose heavy fines on men who touch a skip, or who assist a wheeler, or who work a double shift, or who commit the horror of desecrating the sanctity of a pay Saturday by working. They will indeed permit managers, for purposes of safety or convenience, to reduce the width of an 8 yards bord on condition that a high yardage rate is paid in addition to the 4s. 2d. per ton paid for hewing the standard seam of 5 feet and upwards in the northern district. Extra rates are paid for every inch a coal-seam is under this thickness, and if the cleavage-planes are not plumb extra rates are also paid. If, however, the coal is of a greater thickness than 5 feet no concessions or easier hewing rates are given to the owners, nor will the oppressed workmen allow any concession from the hewing rate should the owner change the system of mining to suit altered conditions. Practically the manager cannot discharge a workman in this highly-favoured district.

On account of the absurd conditions and rates ruling in the Newcastle district, a number of the suggestions contained in Mr. Walker's paper, especially having reference to the dimensions of pillars, cannot be given effect to, the charge for yardage being prohibitory; the high yardage rates (6s. 8d. to 9s.) paid for cut-throughs and headings make the formation of large pillars an expensive affair; and when it is considered that no allowance in excess of 2d. is permitted for working pillars whether large or small, the inducement to secure safety by forming large pillars is more than counterbalanced by the desire to effect a reduction in the cost of production. The union will permit of no alteration in the rate of remuneration whether the system be bord and pillar, open or wide wickets, or longwork, nor do they allow any concession in the case of the manager substituting 16 for 4 yards pillars. Where no alteration is possible in the mode of working, when circumstances due to depth or alterations in the roof or floor, or in the character or condition of the seam arise, no wonder the Newcastle coal trade languishes.

Although the conditions are altering in almost every colliery the majority of managers covertly oppose any attempt to introduce systems of mining suited to the altered conditions, nor will they render any assistance in breaking down the irrational opposition of the men to any proposal that will in any way interfere with the absurdly high standard hewing-rate of 4s. 2d. per ton, and extras for working double shifts, for cleavages off the plumb, for bords under 8 yards wide, for a soakage of water in a working-place, for stone in excess of 4 inches thick in a coal-seam, for working-places on the cross-cut, etc.

The tenacity of the workmen's unions in maintaining, irrespective of consequences, the high standard of wages that has characterized the history of mining in the Newcastle district, their selfish insistance that every workman must be a union man, and their aversion to labour-saving appliances, or to sanction improved systems of mining for fear of its interfering with the standard hewing-price, are undoubtedly causes of the depression that prevails. The country cannot longer stand the strain of the high rate of wages, yet the sorrowful spectacle is seen of some thousands of workmen begging for eleemosynary assistance with an utter absence of sturdy independence, clamouring for State aid and for work which they will refuse unless a high rate of wages is tendered.

It has been truly remarked by English writers that British coalowners have little to fear from Australia while colonial workmen receive the present high rate of wages.

In the south the labour conditions are more endurable. The coal is easier gotten, and it is paid for at a lower rate; the standard rate for bords is 2s. 4d. per ton, increasing with the diminished thickness of the seam; lower rates are paid for open wickets and for longwork, but in the latter mode of working the saving is expended in brushing and building, so that the full advantage of this system goes to the miner. The introduction of coal-cutting machines in the near future will entirely alter this. The excellence of the roof and floor, the freedom from faults, and the ease with which the coal-seams are undercut and come down, should enable large reductions in the cost of production to be made by the introduction of machines. The opening up of new markets and the overcoming of the prejudices of people ignorant of the calorific qualities of steam coal, have obliged the collieries to dispose of their produce at a lower price; the capabilities of production, however, have increased at a greater rate than the expansion of the trade.

In this district various methods of winning are practised, longwork, open or wide wickets, and bord and pillar, and all paid for at different

prices. The prevailing method of winning, however, is bord and pillar, and on account of the rolls this must of necessity be continued. At Mount Kembla colliery the introduction of electric coal-cutting machines into the southern districts of that colliery is at present under contemplation.

Until a few years ago, the small coal was burnt in enormous heaps on the mountain sides; this necessitated the railway wagons being taken up steep inclines to the screens or adit mouths. Now that the prejudice of buyers has been overcome, there is a great and growing demand for small coal, and in consequence one of the most recently-opened collieries send down their skips to screens erected in the valleys below, and it is more than probable that when the demand increases in excess of the capabilities of the inclines one or two favourably situated collieries may follow suit as a means of increasing their output. As a rule the capacity of these inclines may be taken as being from 700 to 1,400 tons in nine hours, and their gradient from 1 in 4 to 1 in 2½.

Faults and Dykes.

With the exception of the rolls in the floor, the district is remarkably free from faults. In a distance of 12 miles only four or five faults have been met with of any consequence; a riser to the north of about 90 feet intersects Bulli colliery; a dipper of 30 feet north intersects Mount Keira and Mount Pleasant collieries; a riser to the south of, it is supposed, 100 feet intersects the southern part of Mount Keira colliery, while a riser to the south-west of 12 feet intersects Mount Kembla workings (this is a reverse fault). Several faults exist in the exploring tunnel of the Southern mine under Mount Kembla, but probably no other tract of coal exists having so few or insignificant breaks of continuity. These faults have a general course a few degrees north of west, but they are inclined to curve. In one or two cases, as in North Illawarra, No. 1 tunnel, Bulli and Metropolitan collieries, dolerite has issued from the line of these faults and has become interlaminated in two bands in the coal-seam, destroying its substance. (See Figs. 3, 4, 5, 6, 7, 8, and 11, Plate IX.)

The whole of the low-lying land between Mount Kembla and the coast is one mass of basaltic rock or scoria, that has issued apparently from fissures or crevices. The same applies to the environs of Wollongong, as well as the coast land as far as Bulli.

Referring to Fig. 1, Plate VIII., masses of greenstone are seen at various points. A few miles behind Mount Kembla, and apparently following the valley of the Cordeaux, greenstone can be traced to the

valley behind Bulli where it appears again in massive form, and this probably passes northwards between Metropolitan and Stanwell Park destroying the Coal-measures in its course. The southern group of the Five Islands also consist of greenstone; this point on the mainland consists of compact basalt. Basalt is seen at Wollongong, Signal Hill, and 3 miles north at Torragghi.

A line drawn from Five Island Point to Wollongong Harbour passes in front of South Bulli colliery and between that and Bellambi colliery through Bulli. This is the line of the thick greenstone dyke that has been partially cut in Bulli; it has not yet been seen in Bellambi, but exists and will yet reveal itself. This dyke crosses an older dyke in South Bulli colliery, which has a trend a few degrees south of west, and is 30 feet in thickness; it will also intersect two similar dykes in Bellambi colliery, and it is probable that the large dyke to the north of Bulli tunnel has an intimate connexion with this one.

The south-western dykes that it intersects consist of dolerite of a yellow creamy colour that does not seriously damage the coal-seam any distance from their course, but the north-western dykes appear to have had a most disastrous effect: the coal in patches is coked from top to bottom, and this for some chains distant, while in Bulli after some years of arduous labour the company have, meantime, abandoned the attempt to cross the coked belt of coal; in some parts of this colliery the coal has been reduced to a cinder and has lost all its characteristics (Fig. 11, Plate IX.).

The behaviour of dolerite, although the result on the coal-seams is the same, is somewhat different. The main dyke or body of greenstone to the west of Mount Kembla, although it has never been systematically traced, maintains a north and south course, while the dykes at South Bulli and Torragghi on the coast have a north-westerly trend, and apparently form a junction with the main body of basalt in the wild and rugged mountain country behind Bulli. These dykes consist of solid greenstone, and in places they contain large masses of schorl and olivine. The dolerite dykes trend nearer to the east and west, although some of the smaller of these have a north-westerly course. They are as a rule as soft as putty, and as unctuous as soap; in patches they are hard. The coal is always coked contiguous to the point of contact; these very often do not occur as dykes, but sometimes issuing from the floor they cut through the coal, and instead of passing upwards spread out in a layer above, or become interbedded with the coal, coking and destroying it. Occasionally these floating masses of basalt warp about in the most

fantastic fashion (Figs. 3, 4, 5, 6, 7, 8, 9, 10, and 11, Plate IX.), sometimes forming one or more beds within the coal-seam, follow it for long distances, and they disappear as suddenly as they make their appearance. In some cases the coal for long distances (over 20 chains as in No. 2 tunnel, Bulli colliery) is coked above and below, leaving the centre divisions more or less unaffected, evidently from the passage of heated gases. In these cases the division of the seam which is unaffected has been preserved by a thin aluminous layer, through which its spent heat evidently could not penetrate.

In some cases the upper seam is unaffected, while the lower or Four-feet seam is burnt to a cinder, by floating layers of dolerite that apparently were unable to penetrate the 35 feet of coarse sandstone that separated them (Figs. 3, 4, 5, 6, 7, and 8, Plate IX.).

In short, when dolerite of a creamy colour is met with there is no certainty when it may disappear. It is difficult to account for the reason why dolerite should extend for long distances and become interlaminated with the coal, or be injected into its substance, unless it is due to the resistance of the thick sandstone deposits overlying the Coal-measures and the dolerite spreading out along the line of least resistance.

From this cause in No. 2 tunnel, Bulli colliery, large areas of the coal-seam have been cindered, and from the fatal effects of the east and west fault, as well as the dyke that intersects Bellambi and Bulli, the old tunnel at present has been greatly crippled. Several acres of cindered coal have been passed through west of this dyke in South Bulli colliery, but the extensive workings of this colliery are now beyond the influence referred to. A few acres of Mount Keira colliery have been affected by a layer of cream-coloured dolerite in the top of the coal-seam as shown. So far no burnt coal has been seen in the upper coal-seam south of Mount Keira; north of Bulli, North Illawarra, No. 1 tunnel has been driven 20 chains in coal absolutely ruined by the presence of two horizontal layers of dolerite. A few soft clay dolerite dykes occur in Coalcliff and South Clifton, but do no damage. North of Coalcliff the sandstone in the railway-cuttings bears evidence of being burnt, while irregular patches of soft pink-coloured basalt tell a tale of havoc in the underlying coal-seams.

Near here, two borings show 10 feet of solid basalt overlying the coal-seam, and although the coal must have been scorched to a cinder the records of the borings make no reference to this circumstance. One mile to the north-west, at Otford, above 700 feet in depth, 7 feet of white dolerite was proved underlying or interbedded with the upper coal-seam, which was cindered, but not so recorded, while at the Metropolitan

colliery, 3 miles west, a basalt dyke is seen at the railway station, and contiguous to the shaft of the latter, dolerite has issued from the fissure of a large fault and spread in two layers in the coal-seam sufficient to cinder it to the south and east of the shaft, and as far as it has been explored in that direction.

Between this and Sydney basalt appears at various points; indeed it may be taken as a general rule that every gully or ravine has been formed by the rapid decay or yielding of dolerite to the weather. It would appear from the physical evidences that the Illawarra coal-field west of Bulli and north of Bulli and Clifton, extending north-west to the Metropolitan colliery, is probably a basaltic zone in which the coal is of no value. East, west, and north of this is a *terra incognita* practically unproved by colliery workings.

Resources of the Illawarra Coal-field.

For all practical purposes the Illawarra coal-field, so far from possessing incalculable quantities of coal, is confined to the few collieries referred to. Every acre containing coal of value has been acquired. Although the series contain many seams of coal, the lower coal-beds on account of their inferior quality and numerous stone bands are unmarketable or unworkable, the only exception to this may be the Four-feet seam in Bulli, South Bulli, Corrimal, and Mount Pleasant collieries. In these this coal-seam is workable, but the quality is so much inferior to that of the upper coal-seam that it is practically unsaleable at present; its day may come, but not until the upper seam approaches exhaustion. The only workable or marketable seam is the upper one already described, the demand for which is steadily increasing in all the colonies, and this must continue while steamers increase in numbers and industries become established. It is the only steam coal worked in Australia.

South of Mount Kembla the lower coal-seams crop out in the eastern cliffs; in places they are much affected by basalt dykes. The writer can perceive no value in these thick and many-banded coal-seams.

The limits of the upper coal-seam are confined to the ranges between their sea-face and the main body of basalt behind, or to a distance of, say 3 miles inland. The country west of the range is too rough and difficult ever to hope for shafts being sunk or railways being made there to convey minerals; they must all be drawn from adits debouching on the sea-cliffs. From the variable thickness of the seam, and the serious extent to which it has been affected by intrusions of dolerite into the substance of the coal itself, a large portion of the frontage north of Bulli and south of Kembla

is of no value. The whole area of workable upper coal will not, exceed 18,000 acres, and the total available quantity of coal after due allowance is made for loss and for rolls, etc., may be, say 145,000,000 tons.

To the south of Mount Kembla and north of Bulli the Four-feet coal-seam thins out. It is of course only a coincidence, but this coal-seam appears to thicken and thin in sympathy with the upper coal. Between Mount Kembla and Bulli collieries it averages 4 feet in thickness, containing as a rule one thin stone band; it is thickest in South Bulli and Corrimal collieries, where it averages 4 feet 3 inches. This is a soft coal breaking into small cubical pieces, and does not bear handling or transport. Its quality is inferior to that of the upper seam, and it cannot be sold in any quantity at present. The sale for such a coal will of course increase with an increase of home industries, and this market is expanding steadily.

From recent and present experiences the writer is dubious whether the coal-seams in the district underlying the upper seam will not be found to be affected by dolerite dykes to a greater degree than is found to be the case in the upper seam, the only one where any extensive operations have been conducted. Appearances would seem to indicate such a result. Assuming that the Four-feet seam is as free from the influence of dolerite as the upper coal-seam, and that the western limit marked by the occurrence of basalt and impracticable country is, say, 3 miles from the line of the grand escarpment of Hawkesbury Sandstones forming the coast ranges, not more than 11,000 acres will be found to contain this seam of a thickness of 4 feet. The writer is not aware of any rolls being found in this seam, and if worked by long-work and coal-cutting machines a total of under 50,000,000 of tons may be assumed as available from this seam for the use of posterity. No estimate need be made at present of the worthless coal-seams underlying the Four-feet seam. The bulk of the upper coal-seam is contained in five collieries. This estimate does not include the resources of the Metropolitan colliery or the country lying to the north and west.

Extensions of the Coal-field.

Referring to this extensive tract of land, a borehole (No. 6, Fig. 1, Plate VIII.) was put down a few miles north-west of the Metropolitan colliery, which is 1,030 feet deep, and although the coal-seam in this colliery dips as much as 1 in 7 west, it was reached in this borehole at a depth of 1,100 feet—a depth that raises some doubt as to the continuity of the seam. At No. 7 boring, 10 miles north, on the Holt Sutherland estate, the same coal-seam was found 4 feet 2 inches thick at a depth of 2,228 feet. At No. 8 boring, 10 miles west, near Liverpool, the upper and Four-feet

seams were apparently absent or represented by a few inches of coal, while the thick persistent dirty seam was found 6 feet 6 inches thick at a depth of 2,680 feet. At Cremorne, No. 9 boring, on the shores of Sydney Harbour, the upper coal was reached at a depth of 2,880 feet, and about 8 feet 6 inches thick, the bottom portion being worthless, but the coal was burnt to a cinder, and, as is common when near to a disturbance, the joints were full of calcite. The borehole was unfortunately placed in the vicinity of basalt dykes; it passed through basalt, but, when the number of basalt dykes that radiate into Sydney Harbour is considered, and the fact that to their agency the configuration of that wonderful harbour may be due, no surprise need be felt at the result of Cremorne borehole, its fate was foretold months before it reached the coal. After proving cinder coal it was continued for scientific purposes by Government. To continue a borehole known to be in disturbed ground for scientific purposes appears to be inexplicable. As might have been foreseen nothing was proven. It has been asserted by Government officials that the effects of the basalt found in this borehole and the cindering of the coal-seam would prove only local. For reasons above given that is not the experience at the collieries where their effects have been most felt; indeed, so far from its effect being a local one or circumscribed, experience goes to prove that the influence of dolerite on coal-seams is not localized, but is widespread and far-reaching and disastrous, and may extend for many chains (for more than 1 mile in the case of the Bulli colliery) over indefinite areas, and much too far for the resources of any colliery company.

Very few people in the colony appear to have given any serious consideration to or have formed a definite idea of the widespread and disastrous effects of dolerite upon the coal-seams. The capricious and persistent manner in which it spreads along the bedding in layers, or becomes injected into the substance of the coal over large areas, or cinders the coal (evidently by the passage of heated gases through the siliceous roof or floor), is truly remarkable, and, so far as the writer is aware, is unique. It is with the knowledge of these circumstances that the writer regards with alarm any attempt to float a company to provide the enormous cost of sinking and equipping a colliery of nearly 1,000 yards in depth (where labour is scarce and dear, among faulty and open-jointed sandstone rocks contiguous to the ocean, in the hope of winning coal under a harbour intersected by numerous basalt dykes, some of which, true to their character in the south, spread out into the coal-seams). It would be an experiment of a costly kind, and incur a risk that the writer does not think any cautious or experienced engineer would care to undertake if a successful result

were the object of his ambition. So far as the writer can see it would be little else than a gigantic gamble and speculation, which, from their frequency in these colonies, should be repressed, not encouraged.

The result of the numerous deep bores that have been put down around Sydney has been far from satisfactory or reassuring. The borehole (No. 7) at Holt Sutherland, 2,460 feet deep, proved the upper coal only about 4 feet in thickness; that at Liverpool (No. 8), 2,680 feet, proved that the upper coal as well as the Four-feet seam were absent in that place; while the borehole (No. 9) at Cremorne, as stated, upwards of 2,880 feet, proved that the upper seam, although of an average thickness, was cindered by the presence of dolerite, and that the lower seams were of no commercial value. The fact is that the presence and influence of these intrusive rocks has determined and reduced the practicable limits of the Illawarra coal-field, regarded by all previous writers as the largest and most valuable of our colonial coal-fields, to one, as has already been stated, of insignificant dimensions.

In computing the resources of these coal-fields no allowance appears to have been made for the capricious character of the coal-seams, the unmarketable quality of the majority of them, or the circumstance that, with the exception of the deep measures around Sydney, almost one-half of the southern and western coal-fields consists of a network of gulleys and ravines, which have been eroded through the Coal-measures, and the major portion of the surface consists of impracticable country, unapproachable by any railway, and under which the continuity and the quality of the coal-seams has not been proved.

South of Mount Kembla, on the Bong Bong Ranges the lower coal-seams are exposed on the slopes. Some of these, over circumscribed areas, apparently improve in quality, but on close inspection are found to contain bands of clay or stone that would much detract from their value. The ranges in this neighbourhood have been intersected by numerous basalt dykes that must exercise a powerful influence on their successful development.

The writer has not taken this portion of the Illawarra coal-field into account in formulating his estimates of the available coal.

Iron Ores.

The coal-seams are separated from each other by evenly-bedded strata, principally sandstone and "faikes," of alternate laminations of sandstone and dark siliceous shale, but there are no chert or conglomerate posts as in the Newcastle measures. Towards their base, dark and grey shales pre-

dominate, and in the east, in some localities, irregular and nodular bands of ferruginous marl and rather poor clayband ironstone occur; but there are no very distinctive strata by which coal-seams can be identified, and no conglomerates, such as are found in the Newcastle measures.

A good deal has been written, and much enthusiasm displayed, with the object of developing, by means of English capital, the so-called Illawarra iron ores. With an intimate knowledge of the district, the writer confesses that he has not yet seen or been shown a single bed of ironstone that has proved to be persistent or sufficiently rich to induce even prospecting. The writer has been shown what was supposed to be blackband ironstone that occurred in a bed 3 feet thick, with coal. This, however, was really limonite that was found (as is common throughout the district) contiguous to a dolerite dyke. Limonite, in apparently large masses, is found in all the southern districts. The masses have, as a rule, cup-like edges, and in the centre a cavity that contains water; the ironstone is but a deposit from these chalybeate springs. These ironstones, however they may be spread over the surface, are of no depth or importance. The deposits of Mittagong in the south, Piper's Flat in the west, and others which are believed to contain millions of tons, have been proved to be only a few feet in thickness. These contain an excess of alumina and silica, and are consequently most difficult to treat in the blast furnace. The chocolate shales that are considered to mark the limit of the Hawkesbury Sandstones have been calculated by some of our engineers among our ironstone resources. They are ferruginous shales, containing an extremely variable percentage of iron, sometimes as high as 18 per cent. To call these ironstones is but an insult to intelligence, as the analyses of stones from the following situations prove:—

	Stanwell Park. Per Cent.	Clarence Siding, Blue Mountains. Per Cent.
Sulphur and loss	·62	—
Silica	59·86	52·55
Ferric oxide	26·85	39·12
Alumina	2·50	3·45
Magnesia	·73	—
Phosphoric acid	1·27	—
Water	8·17	4·98
	100·00	100·00

An average of eight samples from Wollongong district contained 9 per cent. of iron. Fair deposits of moderately good iron ore do occur beyond the limits of the Carboniferous rocks; but a description of these would be outside the scope of this discursive paper. The so-called hæma-

tites found at different points of this coal-field are, in the writer's opinion, entirely due to the deposition of chalybeate waters near to basaltic intrusions, and are of no importance as sources of iron.

Western Coal-fields.

The Blue Mountains begin a few miles west of Penrith. The sandstone ranges rise abruptly from the level of the Emu Plains; the line of the ranges is roughly the course of a large riser west fault of probably 3,000 feet; this fault may be considered to mark the eastern limit of the western coal-field.

The strata in the southern and Illawarra coal-fields dip north-west, occasionally west, but as a rule towards a point west of Sydney. The northern or Newcastle strata have a general dip to the south and south-west, while the strata in the western coal-field dip east or north-east. So far as our knowledge extends the dips might be considered to focus at a point somewhat near to Penrith, or probably eastward of this township.

The Coal-measures at Katoomba are about 300 feet in vertical thickness, and these thin off towards the north.

At Katoomba, the upper coal-seam of Illawarra has been opened up; where opened it measured 4 feet in thickness, but rapidly diminished to the north, and to the east and west it is only of workable thickness over a few acres. Ten miles south, on the summit of a remarkable projection of the Blue Mountains, another very limited patch occurs, but from its isolation cannot be worked.

A few miles north of Katoomba, in the deep valley of the Grose, a larger area of this coal occurs, ranging from 5 feet to 6 feet 6 inches, but here also the seam thins off within 300 yards of the position where it is thickest. In this locality the tops of the highest eminences are covered with basalt, the effect of which on the coal-seams has not yet been ascertained, the natural difficulties to be overcome in conveying coal over such gorges as the Grose, 2,600 feet in depth, being very great.

The Lithgow seam, upwards of 6 feet in thickness, is the lowest coal-seam in this series, but it is only found of workable thickness over the areas held by the five existing collieries; a mile to the dip the same seam is unworkable.

On one part of Megalong, under an enormous irregular mass of rocks projecting out into the Kanimbla valley near Katoomba, the section of this coal-seam contains two 9 inches bands of cannel coal.

The only other coal-seam in this district is the dirty seam, built up of thin layers of coal and of white aluminous claystone, and this seam is

persistent throughout the three southern districts. In certain localities, as on the flank of Mount Kembla in the Illawarra district, and at Cullen Bullen on the extreme margin of the western field, 120 miles from Sydney, there exist localized patches of fairly workable coal in the bottom of this seam, but these are of no extent. At Gladstone near Katoomba in the western, and at Ringwood and Mittagong in the southern coal-fields, large sums of money have been squandered in a vain attempt to work this unmarketable and worthless coal-seam. In parts of this district some of the other seams thicken locally, but cannot be clearly identified by reason of the nondescript and variable character of the strata. The upper and lower coal in this district are essentially capricious and erratic; they are really wandering seams, and do not, excepting at Lithgow, extend over any very great area. Excepting the upper, and one patch of the thick or dirty seam on the western crop, the lower seams are coarse and lustreless, and contain a very large percentage of ash (12 to 35 per cent.). They are practically of no commercial value.

In the southern district these various seams are best developed in the gorges contiguous to Mittagong, where, however, they are rendered useless by the presence of numerous basalt dykes. The huge mass of Gibraltar and of the Jellore Mountains in this district consist of trachytes and recent basalt, and give some indication of the havoc that these cause to the Coal-measures. At Moss Vale, the Coal-measures do not exceed 200 feet in thickness, and contain only two thick seams of no economic value.

Some miles farther south, at Bundanoon, a small area of the upper coal has been worked to a limited extent, but has been abandoned. Neither in this or in the western district is this a steam or semi-anthracitic coal. Attempts to open up the southern coal-field have not been attended with success, although large sums of money have been spent and lost in opening collieries.

At Colo Vale, Mittagong, Berrima, Moss Vale, Ringwood, Bundanoon, and Wingello, the quality of the coal is singularly inferior and quite unsuited for steam raising purposes, so that consumers prefer to use products of distant districts.

Kerosene Shale.

The Carboniferous series south and west of Sydney is remarkable for containing at certain horizons and localities that peculiarly valuable and unique mineral erroneously called kerosene shale, but more properly kerosene coal. This, in its best form, is a superior torbanite; it occurs

in three different horizons, two of these are inconstant, but in the third kerosene coal is found over a wide area though always in circumscribed lenticular and capricious deposits; it is of variable quality and thickness, and is evidently the result of a segregation or deposit of the pollen of wax yielding plants in tranquil waters. Although found in particular positions or horizons it is remarkable for its want of continuity and for the isolation of its deposits; it occurs in lenticular and perfectly circumscribed basins or deposits thinning off towards the margins, the thickness being, as a rule, replaced by thin laminated carbonaceous shales. These resemble the deposits of Bathgate or Torbanehill, or the finer qualities of gas or cannel coal in Great Britain. The position of the most valuable deposits of this wonderful mineral, which yields in its best state about 18,000 feet of 50 candle-gas or 170 gallons of crude oil to the ton, is about 25 feet above the Lithgow coal-seam or at the base of the series.

At Mount Kembla, over a small area to the south, a 2 feet seam of kerosene shale was worked and distilled into oil. The shale, poor in quality, yielded 60 gallons of oil. It has a siliceous base, can be split into slabs of any size, and is flexible, and is in reality itacolumite.

Resources.

Regarding the available resources of our coal-fields and excluding the East Maitland and Greta series which extend as a fringe beyond the outcrop of the Newcastle coal-field and presumably underlie that series, excluding also the lower and worthless seams of Illawarra and the large portion of country unexplored and impracticable for surface transit of minerals west of the coast ranges (which moreover has been the scene of stupendous volcanic forces), excluding also the thick, faulty, and inferior lower coal-seams cropping out on the escarpment of the coast ranges south of Mount Kembla, the available quantities of marketable coal appear to be as follows, viz.:—

	Tons.
1.—In all the coal-seams within the limits of the Newcastle district and extending under the sea	940,000,000
2.—From the upper coal-seam of the Illawarra district... ...	140,000,000
From the Four-feet seam, ditto	47,000,000
3.—From the deep coal measures north of Coalcliff and south of Sydney	320,000,000
From the Four-feet seam in the deep measures	150,000,000
4.—The western field from the Lithgow seam	15,000,000
In upper coal-seam in the margins of the Grose and Jamieson valleys	15,000,000
Total resources	1,627,000,000

Or equal to nine years of the present output of Great Britain; while there is abundance of cheaply won and easily accessible upper coal in the Illawarra collieries, the deeper measures with their risks and uncertainties and the harassing enactments which are threatened are unlikely to be exploited for many years. It is almost impossible, considering the broken character of the country, the small area of coal that is opened up by the railway, and the inferior and capricious character of the seams, to give an exact estimate of the available coal in the western district. To the north, among the wild gorges, of which little is known, considerable deposits of coal exist, but are worthless without easy and cheap transit to the seaboard. For the same reason the high ash and third-rate coal-seams on the southern railway are excluded from the foregoing estimates, owing to their inferior quality and proved inadaptability to present requirements.

Correlation of the Northern and Southern Coal-fields.

The city of Sydney and its marvellously lovely harbour rest on the upper members of the Hawkesbury Sandstone. Towards the city or its neighbourhood the Coal-measures of the Illawarra, southern, western, and Newcastle or northern coal-fields dip. Although the southern coal-seams have been traced under Sydney, the northern coal-seams have not been proved by borings beyond 13 miles south of Newcastle. Boreholes put down to depths approaching 1,800 feet in the Awaba parish practically proved no coal. At Wyong, 62 miles north of Sydney, two coal-seams of no great value were found at 900 feet and 6 feet thick. At Dora Creek, 17 miles farther north, the same seams were found at 372 feet and 6 feet thick, but in the situation evidences of basalt are apparent. These should probably be correlated with the Wallarah coals, 16 miles south of Newcastle, on the Pacific coast, which are undoubtedly on a higher horizon than the Great Northern coal-seam, formerly believed to be the upper seam of this series. The position of the Wyong and Wallarah coal-seams with respect to the Newcastle measures has not as yet been proved by borings. Much has been said about the identity of the Wallarah and Illawarra upper seam, but no two coal-seams could be more dissimilar in appearance and character than those of Wallarah and the upper seam of Illawarra. In the latter district the other seams occur in close and orderly succession, while at Wallarah there is an interval of strata which are utterly dissimilar from any in Illawarra that have not as yet been pierced or proved. Between the neighbourhood of Sydney, say west of Paramatta, and the western district a large fault exists, the course or trend of which has not been traced.

From this circumstance of the general dip the inference is that the coal-seams in these districts are identical. This was the writer's belief some years ago when he had less knowledge of the district geology, and when less was known of the geology of the coal-fields as revealed by recent mineral workings, deep sinkings, and bores.

On closely studying the character of the strata in different districts the writer can, however, discover no point of analogy between the Newcastle district and those in the south and west. There is not the slightest evidence of identity between the strata composing the series or the coal-seams. The assay and quality of the coals are entirely different. In the last published Blue Book considerable space is devoted by Mr. David to the discussion of the identity of one or other of the northern with the southern coal-seams. The reasoning is based on negative and imperfect data, and is supposititious and entirely ignores the very points that a mining engineer would first look for in correlating different strata. Mr. David comes to no positive conclusion.

Before discussing the identity of strata that are so devoid of fossiliferous evidence and of salient features by which certain stratifications and horizons can be distinguished or determined, it would, in the writer's opinion, be of more importance to work out the physical geology of the district; and this in a colony where there is but a limited output and market, where in consequence the proving of the deep measures over a large area of broken country, must necessarily be a work of time. The effect of faults has not as yet been considered, and some of these doubtless will yet prove a material factor in discerning or finally determining the identity of the strata. There is no visible resemblance between the strata of the southern and those of the Newcastle coal-fields.

If, on the other hand, it is assumed that the southern Coal-measures correspond with the East Maitland or Rathluba (underlying the Newcastle series, probably 1,500 feet or so)—and the strata of these two coal-fields, although by no means identical, have, the writer confesses, a few general points of resemblance—if they are identical, what has become of the Newcastle Coal-measures in the south, measuring, say 1,500 feet?

On the East Maitland series is superimposed 1,500 feet, principally composed of black shales, and over these 1,200 feet to 1,500 feet of the Newcastle Carboniferous measures. In Illawarra, these 3,000 feet of strata are absent, and the Hawkesbury Sandstones are directly superimposed conformably on the strata overlying the coal-seams and also conformable with them, while to the west the coal-seams rest on Palæozoic rocks.

With respect to the statement that the strata at Wollongong are identical with the marine beds of Greta, the writer confesses that with an intimate knowledge of both he can perceive no analogy or similarity. The Greta beds consist of great posts and conglomerates and drifts enclosing small boulders and detritus. Those of Wollongong are of a greenish sandstone. This locality, however, has been the theatre of so much volcanic disturbance that any hypothesis based upon the supposed unconformity of the beds could not be accepted as affording reliable proof in support of any theory establishing their age or identity with any of the northern coal-fields. The lower coal-seams of Illawarra rest upon conformable strata, and of this there need be no doubt. The even deposition of these beds can be closely studied in the slopes of the high ranges south of Kembla, and on the sea-cliffs at Coalcliff.

It is scarcely conceivable that Coal-measures of such thickness and of such importance as the Newcastle coal-field, and possessing so many negative evidences of their identity should be unrecognizable 70 miles distant or so on the opposite side of the basin. The appearance of the coal-seams, the mode of their occurrence, their quality, and the character of their strata are entirely dissimilar.

In endeavouring to correlate the northern and southern coal-fields one requires to ignore so many opposing circumstances, and to take such leaps into the obscurities of supposition for the purpose of establishing a position more or less chimerical, that the train of reasoning must necessarily be so faulty and unedifying that to continue the discussion in the absence of direct or at least reasonable proof would be unprofitable. Greater service would be rendered to science and to the industry of coal-mining if the enthusiasm that has been devoted to a premature and profitless discussion of the identity of the northern and southern districts had been given to elaborating the physical geology of the coal-fields and intervening country, and in tracing the course of faults and dykes, the presence of which are likely to have a weighty and peculiar influence on the future of colonial coal-mining. To trace and accurately map the course of these disturbances, to study their occurrence and effect on the coal-seams they intersect, would be, the writer apprehends, labour devoted to a better purpose than perpetuating the ludicrous absurdities of reproducing calculations of coal resources of a misleading character, or of wasting time in purposeless and inconclusive dissertations on the correlation of the coal-seams based on hypothetical and insufficient premises.

Mr. G. Blake Walker (Barnsley) wrote that he had read Dr. Robertson's paper with interest, but thought it would be presumptuous to traverse any of the statements as to the geological features of the district, made by Dr. Robertson, who had for so many years had every opportunity of studying them, and who was probably the most competent authority on the subject with which his paper dealt. The only point as to which he (Mr. Walker) was not inclined to agree was the surmise he ventured upon, that the southern Coal-measures might possibly be found eventually to correlate with the beds outcropping at Wallarah or Catherine Hill Bay. This was illustrated in his (Mr. Walker's) paper by a section. He gathered from the concluding remarks of Dr. Robertson's paper, although he did not think that there were sufficient data to warrant a confident opinion, that he rather inclined to the same view. Although, as he says, "this is a question which cannot be very profitably discussed for some years to come, still it is not without a certain interest, even while the true facts are in doubt, but eventually it must be a most important one."

Mr. T. E. Forster (Newcastle-upon-Tyne) wrote that so far as the identification of the coal-seams north of Sydney with those in the southern district was discussed, Mr. David based his theory of the possibility of the disappearance of the Newcastle coal-seams on the south side, on an unconformity which might admit of an underground outcrop, so to speak, and owing to which the Newcastle coal-seams might actually exist under Sydney without any appearance to the south. The extraordinary variations both in the seams themselves and in the adjacent strata were such well-known facts that no evidence was to be gained from such points, or would be of much value, more especially as the distances were sufficiently great even in a better known coal-field to account for changes quite as radical both in the nature and position of the coal-seams. Probably Dr. Robertson was right in saying that the discussion was both premature and profitless with the present evidence. The gas which Dr. Robertson mentioned as being met with at the Metropolitan colliery, and of which he gave an analysis, was a very peculiar one. The writer paid a visit to this colliery, two years ago, when it was being opened out and before the erection of the ventilating fan. At that time the gas was very difficult to dislodge from the dip places though the rise workings were usually quite clean. On returning to England the writer sent the analysis to Prof. Bedson, but he did not care to express an opinion upon it without a further knowledge as to the method of analysis, and the writer had been expecting a sample of the gas to be sent home by Dr. Robertson. So far as the wages question was concerned, the southern district had a

decided advantage over the northern coal-field, and an advantage which was at the present time making itself felt. The writer did not, however, think that the heavy yard rates in the northern district would be an insuperable bar to the formation of larger pillars, even when viewed from the point of view of the colliery cost sheet. At one pit, near Newcastle, they had departed from the ordinary custom so far as to try 6 yards bords and 12 yards pillars, and with success. The writer believed that many of the extras which Dr. Robertson complained of are not unknown in the North of England, which bears out a remark the writer had frequently heard in Australian collieries to the effect that all the bad practices were introduced by the "Geordies."

Dr. ROBERTSON wrote that he excluded the consideration of the lower coal-seams of Illawarra for reasons given in his paper, and he also excluded the coal-seams on the southern line and towards Jervis Bay because of their distinctly inferior quality, or unproved area, or existing impositions that render their transport practically impossible. They could not, at present, be purchased at any price. The major portion of the area considered as coal-field was perfectly unproved, and except the presence of enormous masses of igneous or intrusive rocks nothing whatever was known of the coal-seams. The influence of these intrusive rocks, too, had not been weighed or considered. Every day brought fresh evidence of the disastrous effects of dolerite in the Coal-measures; the writer was becoming more and more convinced that the lower seams were destroyed to a greater extent than the upper coal-seam. They had, as it were, acted as safety-valves for the upper seam, which over large areas was perfectly useless from the same cause. The effects of dolerite was not localized but wide-spreading in its effects, and those who thought otherwise would assuredly commit an error in judgment that might ruin the resources of the company they might represent. The writer was at present driving a water-level in a coal-seam 25 feet under the upper coal-seam. The upper coal-seam was unaffected, the lower seam was one mass of dolerite, and they had driven 200 yards in dolerite and cindered coal. The roof consisted of coarse pebbly sandstone, which seemed to have resisted the force of the intrusive rock, and the fluid dolerite became injected along the bedding-planes of the coal-seams under-lying the upper seam. The same experience had been the lot of more than one southern colliery.

Mr. W. Cochrane (Newcastle-upon-Tyne) proposed a vote of thanks to the writers of the above papers, which were upon some of the most interesting subjects that could be put before them, and regretted that the arrangements of the local committee prevented their full discussion that day.

Mr. E. Garforth (Normanton) seconded the motion, and it was passed unanimously.

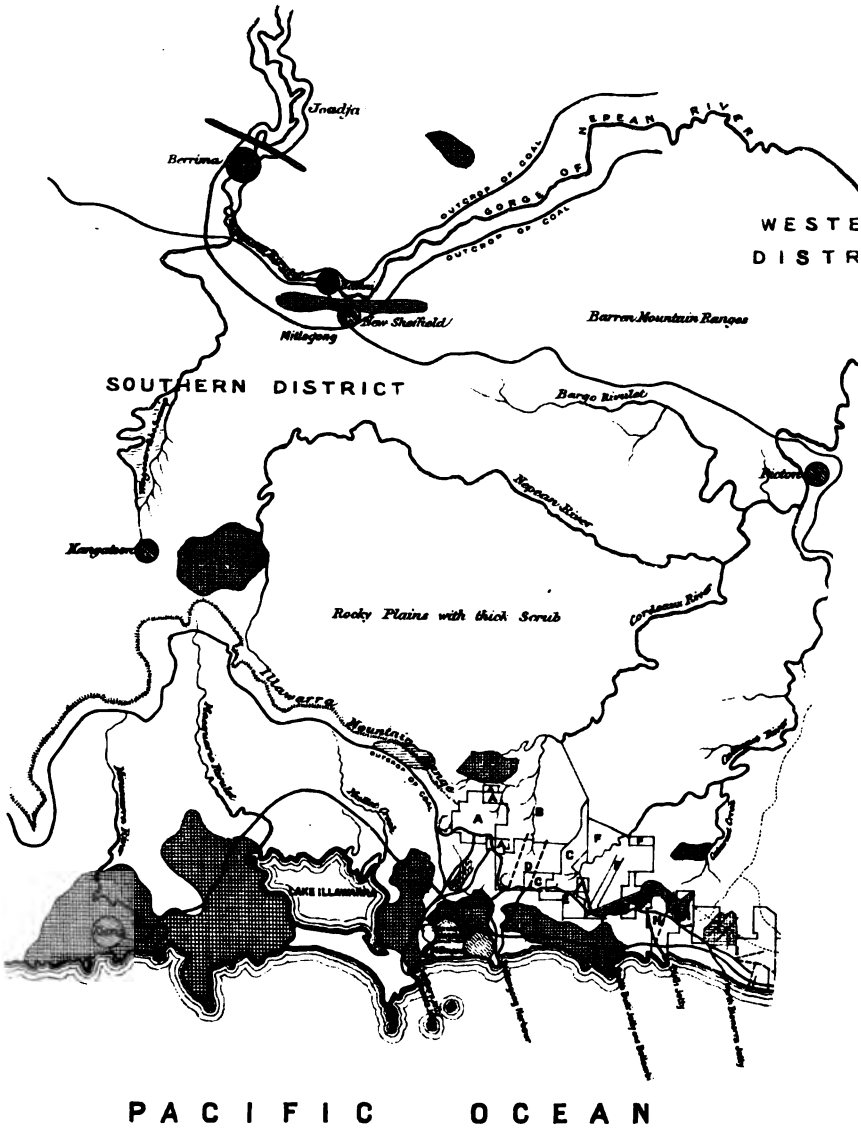
The meeting then adjourned for luncheon.

Mr. W. Burton, F.C.S., delivered the following address when the members returned :—

THE MANUFACTURE OF CHINA AND EARTHENWARE.

This address is intended to give an outline of the processes now in use in order that the members visiting various works in the course of the afternoon may have a more intelligent grasp of the potter's industry. Of course in the old days the only material for making pottery was clay of any description. Now, the clay used for making pots, even of the commonest earthenware, is a very complex substance, consisting of two, three, or more varieties of clay from different localities, together with an admixture of flint, and of china-stone from Cornwall. The basis is of course some form of natural clay, and in the production of earthenware the material most largely used is blue or ball clay, a very plastic substance; but this, if used alone, would be apt to crack, to split in drying, to go out of shape in firing, while it would not readily take a good coating of glaze. In order then to get a compound clay that will stand moulding, shaping, and firing, and will then decorate well, it is necessary to introduce other ingredients. The first addition is china-clay, and the two together form as it were the solid flesh of pottery. In order to bestow upon the ware the properties of hardness and durability it is necessary to add a certain proportion of silica in the form of finely pulverized flint. Ordinary boulder flints are used, they go through a process of calcining which renders the flint beautifully white and easily friable, reducing the grinding power required to about one-half. The grinding process is the simplest contrivance imaginable, and has been in use in the Potteries for about 150 years. The flint is added to the clay in the condition of a thick cream; china-stone, which forms the fusible ingredient of the body, is also added, and the effect of firing is to combine the particles of clay, stone, and flint into a solid homogeneous mass capable of forming a hard,

To illustrate Dr. J. R. M. Robertson's Pap



REFERENCE.

Doleritc and Basalt thus
Cindered Coal thus
Faults

Sc

To illustrate Dr. J. R. M. Robertson's Paper on "The Coal-fields South of Sydney, New South Wales."

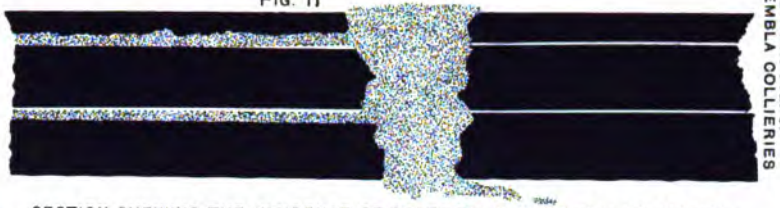
Fig. 2.

CROSS SECTION OF A ROLL IN THE UPPER COAL SEAM
AT ILLAWARRA COLLIERIES

Fig. 9.

SECTION SHEWING THE INCIDENCE OF DOLERITE IN THE FOUR FOOT SEAM,
MOUNT KEMBLA COLLIERIES

Fig. 11

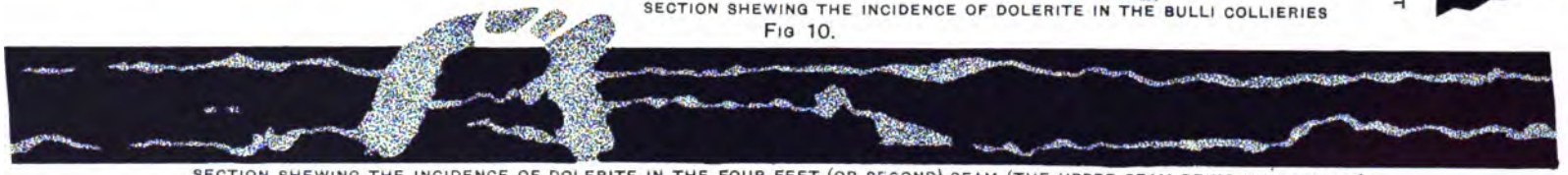


SECTION SHEWING THE INCIDENCE OF DOLERITE IN THE BULLI COLLIERIES

Fig. 12

SECTION OF THE UNBURNT UPPER COAL SEAM (OVERLAYING THE FOUR-FEET SEAM SHEWN IN FIG. 9) AT MOUNT KEMBLA COLLIERIES

Fig 10.



SECTION SHEWING THE INCIDENCE OF DOLERITE IN THE FOUR-FEET (OR SECOND) SEAM (THE UPPER SEAM BEING UNAFFECTED)
AT MOUNT KEMBLA COLLIERIES

Fig. 3.

UPPER SEAM

Fig. 4.

LOWER SEAM

Fig. 5.

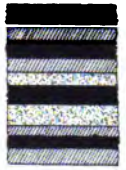
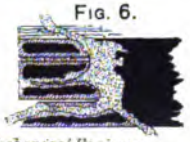


Fig. 6.



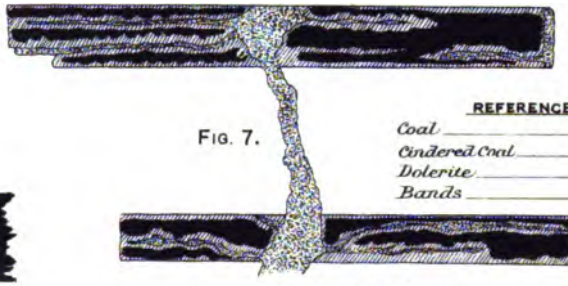


Fig. 7.

REFERENCE

Coal
Cindered Coal
Dolerite
Bands

SKETCHES SHEWING THE INCIDENCE OF DOLERITE
AT THE ILLAWARRA COLLIERIES.

Fig. 8.

And. Reid Sons & Co. Litho. Newcastle

ringing body which will take a good glaze. The four materials are mixed together in the requisite proportions, and the liquid "slip" produced is passed through a number of mechanical sieves so as to clear the dirty particles from it, and the purified slip is then ready to be made into plastic clay. Two processes in this stage are still in general use, the one employed at old-fashioned works being that of evaporation over a kiln, but that process is too costly and too slow for the large works which require from 100 to 150 tons of clay per week; the system generally used is that of filtration under pressure, the water being squeezed out of the material and the clay left almost ready for the hands of the potter. To render it uniform, however, and to remove any air bubbles, it is passed through a pug mill.

The manufacturing processes are then commenced, and the oldest of all modes of working is that of throwing on the wheel. Throwing by hand produces the finest pottery, but owing to competition, the mechanical process of "jollying" has been introduced.

The processes of the first or biscuit firing, and the under-glaze decoration of the ware by transferring printed designs upon it, were fully described.

The hardening-on process to fix the decoration was described, as well as the operation of glazing and the complex constituents of the glazes used.

The ware for glazing was then followed through another, or the glost firing, when it becomes covered with a thin coating of glass or glaze. The farther, or onglaze decoration by hand, in colours and gold, was also explained, as was the process of casting ornaments of china or parian ware.

The difference between earthenware and English china is that the latter contains no ball clay, but a large proportion of calcined bone, which makes so fusible a mass that when submitted to firing it becomes semi-transparent.

The PRESIDENT proposed a vote of thanks to Mr. Burton for his address, which was carried with applause.

Mr. W. E. GARFORTH (Normanton) proposed a vote of thanks to the owners of works and collieries which the members were about to visit.

Mr. SCOTT (Derby), H.M. Inspector of Mines, seconded the motion which was carried unanimously.

Mr. H. LEWIS (Nottingham) moved a vote of thanks to the First Shropshire and Staffordshire Artillery Volunteer Officers for the use of their hall.

Mr. T. SOUTHERN (Derby) seconded the motion, which was carried with acclamation.

Mr. J. B. SIMPSON (Newcastle-upon-Tyne) moved a vote of thanks to the Committee of the North Staffordshire Institute of Mining and Mechanical Engineers for the excellent arrangements made, and remarked that the gathering appeared to be one of the most successful that they had held.

Mr. BINNS (Netherseal) seconded the motion, and said the meeting had suffered from a plethora of papers, but as long as that was the case it would be a good thing for the Federated Institution.

The resolution was carried unanimously.

Mr. W. HEATH (Burslem) proposed a vote of thanks to the President for the manner in which he had occupied the chair.

Mr. W. F. CLARK (Birmingham) seconded the motion, which was passed unanimously.

An interesting collection of objects of interest to the members was shown in the large hall.

The members dined in the evening at the North Stafford Hotel.

The following notes record some of the features of interest seen by visitors to collieries and works, which were, by kind permission of owners, open for inspection during the course of the North Stafford meeting, on September 7th and 8th, 1892:—

CHATTERLEY-WHITFIELD CO.'S WHITFIELD COLLIERY.

MIDDLE PIT.

The winding engine has two 24 inches horizontal cylinders of 5 feet stroke, with 12 feet parallel round rope drum, and balance rope under the cages. It is winding from a depth of 250 yards. Double-decked cages are used, with two tubs on each deck. The average speed of winding and changing the tubs is 50 seconds per run.

About 5,000 tons are drawn per week.

There are two hauling engines: One, on the surface, has two 12 inches cylinders of 4 feet stroke, geared 3 to 1 to a 4 feet 6 inches drum. It is winding up the Hard Mine plane, 350 yards long, dipping 1 in 5, with 12 tubs in a train, each carrying a load of 8 cwts. Another, placed underground, with two 12 inches cylinders of 4 feet stroke, geared 7 to 1, drives the endless-rope haulage in the Holly Lane plane, 350 yards long, dipping 1 in 5, and will ultimately extend to a total distance of 1,300 yards.

A Hawthorne-Davey differential engine is fixed underground: it has an 18 inches high-pressure, and 32 inches low-pressure cylinder, with condenser, and a double-acting 11 inches ram. It pumps 500 gallons per minute from a depth of 150 yards. The reserve pumping engine on the surface has two 24 inches cylinders of 5 feet stroke, fitted with T-bobs, etc.

A Cameron pump, with two 16 inches steam cylinders, and 8 inches rams is pumping from the pit-bottom to the main engine. Small Cameron pumps, worked by compressed air, are used for dip-pumping.

The pit-bottom arch is 19 feet diameter. Four seams—the Ten-feet, Bowling Alley, Holly Lane, and Hard Mine, are in work, and all drawn from one landing. The seams are connected by a cross-measures tunnel. All the workings are on the longwall method.

Separate screens are in use for each seam. There are two fixed bars-screens; one shaker-screen, making three kinds of coal, driven by single engine, 6½ inches diameter and 7 inches stroke; one Wain shaker-screen, with side tippler, worked by friction-gear driven by single engine, 7 inches diameter and 10 inches stroke, with Leys malleable chain belts. Creeper and steam hoist elevators are used for returning the empty tubs to the pit.

Institute Pit.

The winding engine has two 36 inches vertical cylinders, of 6 feet stroke, fitted with balanced slide valves, with 21 feet parallel round rope drum. It is winding from a depth of 421 yards. Double-decked cages are used with two tubs on each deck. The average speed of winding is 40 seconds, and the time of changing tubs is 10 seconds. Double deck hooking-on and banking arrangements are employed, with balance cages, fitted with the Woodworth automatic controlled gear.

About 5,000 tons are drawn per week.

An engine with two cylinders 18 inches diameter and 4 feet stroke, fitted with helical cog gear, 3 to 1, and two 6 feet drums, is fixed underground. It hauls up two separate plane-roads, each 500 yards long, and

dipping 1 in 5, trains of 12 to 14 tubs, with 10 cwts. load on each tub. Another engine, with two cylinders, 8 inches diameter and 16 inches stroke, geared 5 to 1, with two drums, is used for tail-rope haulage on the level.

The pit-bottom arch is 20 feet diameter and 16 feet high, with double deck platform. The Cockshead seam, 7½ to 8½ feet thick, is worked on the longwall system.

The pit-bank of galvanized iron roofing is in course of construction. A Wain shaker-screen makes four sizes, with side tippler worked by friction gear, and is driven by engine, with two horizontal cylinders of 8 inches diameter, with Leys malleable chain belts.

A bucket elevator is used for re-screening slack, and creeper chain elevator for returning empty tubs to the pit. The screen and tippler is designed to deal with 1,000 to 1,200 tons per day of 8 hours, no hand-picking being necessary.

There is a steam crane in use for unloading timber, etc.

Platt Pit.

The winding engine has two horizontal cylinders, 30 inches diameter and 5 feet stroke, with a 14 feet round rope parallel drum. It is not at present winding coal.

The ventilation is produced by two 8 feet and one 12 feet Gunther high-speed fans, assisted by exhaust steam from the underground engines.

General Surface Arrangements.

Upwards of 5½ miles of sidings, and 5 miles of main line connect the collieries with the North Stafford Railway, Biddulph Valley, and Loop Line branches, and with the company's own landsale depôts at Burslem and Tunstall. All the sidings are laid out to work by gravity.

Light tramways are used in the colliery yard to facilitate the transport of materials, stores, etc.

Steam is supplied by ten Adamson steel flued boilers, two 30 feet long by 8 feet diameter, and eight 30 feet long by 7 feet diameter, hand-fired, pumping, winding, hauling, etc. A set of Green fuel economizers of 416 pipes is in use.

The round chimney, 225 feet from ground-line, and 8 feet internal diameter at top, is fitted with the Platt cast-iron wind guard.

The patent fuel or briquette plant consists of a Stevens 50 tons fuel press, with elevators, pitch mill, Carr disintegrator, etc.

There are ample carpenters' and pattern-makers' shop, sawmill, smithy with five fires and 3 cwts steam-hammer, and fitting shop with lathes, screwing, slotting, shaping, planing, and boring machines.

The fireproof lamp-house has conveniencies for 1,500 lamps, and contains a lamp cleaning machine, lamp repairing shop, etc.

The wagon shops are galvanized iron sheds, fitted with wood working machines, smithy, electric light, etc. Upwards of 1,700 railway wagons are maintained in repair.

GREAT FENTON COLLIERIES AND IRONWORKS.

Collieries.

There are four pairs of vertical winding engines, with cylinders 36 inches diameter and 6 feet stroke. Steam is supplied by steel boilers, double-flued, each 30 feet long and 7 feet diameter. The wrought-iron headgears are 60 feet high.

There are three hauling engines fixed on the surface.

Ventilation is produced by two 45 feet diameter Waddle fans, driven by engines 34 inches diameter and 4 feet stroke.

The brick works are fitted with machinery capable of producing from 70,000 to 80,000 bricks per week, on the plastic system, all dried on flues heated by gas from small producers.

Furnaces.

There are two furnaces, each 65 feet high, and 16 feet 6 inches in diameter at the bosh, worked with raw coal. There are seven elephant boilers, and a chimney 180 feet high, and 12 feet square inside. The blowing engines have steam cylinders 33 inches diameter, and air cylinders 66 inches diameter, with a stroke of 4 feet 6 inches. These engines are not coupled together, so that either engine may be stopped for repairs if required.

MIDLAND COAL, COKE, AND IRON COMPANY'S APEDALE COLLIERIES.

No. 5, Burley.

The winding engine has two 36 inches cylinders winding from the Ten-feet, Seven-feet, Eight-feet, and Bullhurst seams, at depths of 306 yards and 480 yards. The mines at this pit vary from 6 feet to 8 feet thick, and lie at an angle of 45 degs.

The boilers are being replaced by tubular boilers.

Guibal (40 feet diameter) and Waddle (35 feet diameter) fans produce the ventilation.

The surface is lighted by electric lamps.

No. 6, Sladderhill.

Winding from the same seams as the other pits at 200 yards depth.

No. 7 and 8 Pits.

Winding the Cannel Mine, Chalky Mine, Brown Mine, and Little Mine ironstones, from a depth of 170 yards.

No. 9, Footrails.

Adits working the Red Shagg and Red Mine.

No. 10, Chesterton.

The winding engine has two 18 inches cylinders winding the Blackband, Red Shagg, and Red Mine ironstones, from depths of 160 yards and 180 yards.

The hauling engine with two 12 inches cylinders hauls up a dip in the Red Mine of 300 yards, 1 in 3.

A Cameron direct-acting pump with a 27 inches cylinder of 14 inches stroke, and 7 inches ram, forces 200 gallons of water per minute to a height of 180 yards.

MIDLAND COAL, COKE, AND IRON COMPANY'S PODMORE HALL COLLIERIES.

No. 1 Pit.

The winding engine with two 36 inches cylinders of 6 feet stroke, and a 16 feet drum, is winding from the Bullhurst and Seven-feet Banbury seams at a depth of 360 yards. Three-decked cages are used with two tubs on each deck. The height of the head gears is 55 feet.

This is the upcast shaft, and is boxed in at the top. The ventilation is produced by a 45 feet Waddle fan.

There are a pair of hauling engines hauling up a dip 700 yards, 1 in 3; one pair of hauling engines, with 16 inches cylinders of 3 feet stroke, hauling up a dip of 700 yards, 1 in 3; and another pair of 18 inches cylinders of 4 feet stroke, hauling up a dip of 500 yards, 1 in 3.

No. 2 Pit.

The winding engine with two 36 inches cylinders of 6 feet stroke, and a 20 feet drum, is winding from the Bullhurst seam at a depth of 530

yards. Three-decked cages are used with one tub in each deck. The head gear is 55 feet high. Nine egg-ended boilers supply steam to the winding and hauling engines.

The electric lighting plant lights the surface and underground workings.

There are shaker-screens, elevators, and nut washing apparatus.

No. 3 Pit.

The winding engine with two 24 inches cylinders of 4 feet 6 inches stroke, and a 12 feet drum, is winding from the Ten-feet seam at a depth of 285 yards.

The mines at this pit vary in gradient from vertical to horizontal.

An endless-rope haulage engine with two 12 inches cylinders hauls from the whole of the workings.

An Evan hydraulic motor pumps the water out of the engine dip district to the shaft, and a Brunt direct-acting pump with 16 inches cylinder of 18 inches stroke forces the water a distance of 90 yards up the shaft.

Shaker-screens and the ordinary fixed screens are in use.

SNEYD COLLIERY AND BRICK WORKS.

No. 1 Pit.

The No. 1 pit is 620 yards deep. The winding engine has two 22 inches cylinders of 4 feet stroke, with a drum 10 feet in diameter. This pit is used as an upcast shaft and is connected with the seams worked by three separate insets.

Ventilation is effected by means of the conjoint effects of three boiler furnaces and the exhaust steam from two hauling engines and one pumping engine, all situated at a depth of 380 yards; and it is intended to put in two boilers and a hauling engine at the depth of 620 yards.

No. 2 Pit.

The No. 2 pit is used as a downcast, and is 621 yards deep. The winding engine has two 36 inches cylinders of 6 feet stroke, with a drum 21 feet in diameter. The pit-frames are 54 feet high, and are made of steel girders. The cages have three decks with two wagons on each deck; each wagon holding 10 cwts.; a winding occupies 50 seconds and the banking 15 seconds.

Five seams are being worked at this pit, from one landing: the Yard coal and Ten-feet seams on one side; and the Bowling Alley, the Holly Lane, and the Hard Mine on the other side. The pit-bottom is 13 feet 6 inches in diameter and of barrel shape.

Hauling is at present being effected by one 16 inches cylinder of 3 feet stroke, geared 3½ to 1, and fitted with an 8 feet drum. It is intended that all the hauling at this pit shall be changed to an endless-rope system.

No. 3 Pit.

The No. 3 pit is used as a downcast shaft and is 382 yards deep and 13 feet diameter. The winding engine has two 16 inches cylinders of 4 feet stroke. The winding drum has a groove, with a diameter of 10 feet; one rope is used for the two cages with a balance rope under the cages. Single-decked cages are used with two tubs of 10 cwts. on each deck. The Burnwood, Mossfield, and Seven-feet seams are worked and drawn from one landing.

The two hauling engines are each fitted with two 10 inches cylinders of 18 inches stroke, geared 5 to 1, with two drums, each 4 feet 6 inches in diameter.

The Hawthorne-Davey pump engines force 24 tons of water per hour to the surface from a depth of 382 yards.

Steam is generated underground by three boilers: two Cornish boilers, 20 feet long by 5 feet diameter; and one Lancashire boiler, 30 feet long by 7 feet diameter. On the surface are six Lancashire boilers, each 30 feet long by 7 feet diameter, which generate steam for all work on the surface. There are also on the surface, an engine with two 12 inches cylinders of 4 feet stroke, geared 6 to 1, and a drum 10 feet in diameter, used for shunting on the railway siding; an engine with two 8 inches cylinders is used for driving the shaker-screens and the Heath and Woodworth tipplers; an engine with two 6 inches oscillating cylinders is used to work the endless-rope on the incline to the town. This incline is 600 yards long and the rope is attached to the tubs by side-clips.

The coal wharf is extensive and arrangements are being made to fit ten new screens with the Heath and Woodworth tippler.

Improved systems of jigging and of safety blasting, and improved shot-lighting lamps are used in the mine, the inventions of Messrs. Heath and Frost.

At the brick works is very extensive plant for making of glazed bricks, firebricks, and other firemarl goods.

MESSRS. THOMAS BOLTON & SONS' COPPER WORKS.

Froghall Works.

The copper is received in a partially refined state from the smelting works at Widnes, and is purified by electrolysis in a sulphate solution, the result being chemically pure copper, which is melted and toughened in the usual way in reverberatory furnaces in 16 ton charges, and cast into billets of about 100 lbs. for subsequent rolling.

The electrolysing plant is very extensive, comprising 550 decomposing vats, each containing twelve pairs of electrodes capable of depositing 4 lbs. of copper per hour. The anodes remain in the vats for about six weeks, the sludge containing notable proportions of gold and silver being removed at intervals. The vats are placed on terraces, with constant circulation of the sulphate solution through them. The electric power is obtained from four triple-expansion engines of 250 to 300 horse-power, working at 150 lbs. pressure, each engine driving by ropes a pair of Elwell-Parker dynamos producing a current of 1,500 ampères at 50 volts.

The electrical plant is also employed to light the mills.

The refinery slag is returned to the Widnes works. The sulphate solution is replenished with blue vitriol from the pickling tanks at the wire works.

Oakamoor Works.

Over 400 workmen are employed at these works, in the manufacture of the copper prepared at the Froghall works into wire, locomotive and marine engine tubes, and other industrial requirements.

In the wire factory, the billets are rolled into rods of No. 5 or 6 gauge at a low red heat in a combined mill, whose breaking-down rolls are driven from the engine, and the finishing train by ropes. After annealing and pickling, the rods are drawn into wire of all diameters down to $\frac{1}{1000}$ inch. The lower numbers, down to No. 20 S.W.G., are drawn through steel plates, but for the finer diameters, ranging to No. 50, of about $\frac{1}{1000}$ inch diameter, diamond plates are used, arranged in continuous series, the wire passing from one hole to another until the required diameter is attained. Some of the thinner electrical wire is coated by running it through a bath of melted tin, this protection being necessary where the wire is to be covered with vulcanized india-rubber. The wire is used for electrical purposes, and has a conductivity 2 per

cent. higher than given by Matthieson for pure copper. A special feature is the hardened wire used by the Post Office and telephone companies for overhead lines.

Seamless copper and brass tubes are drawn for steam and other purposes, and the manufacture also includes rolled copper and brass sheets, solder, etc.

An ingenious machine of American invention for producing dog and cattle chains from straight rods of metal was shown at work.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, OCTOBER 8TH, 1892.

MR. J. B. SIMPSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings of August 6th, September 24th, and October 8th.

INTERNATIONAL CONGRESS OF ENGINEERS, CHICAGO, 1893.

The SECRETARY stated that he would be pleased to receive the names of members who desired to communicate papers to the International Engineering Congress, to be held at Chicago, in 1893, during the World's Columbian Exposition.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

The SECRETARY reported the proceedings of the meeting of the Council held on September 7th, 1892.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JAMES ANGUS, Mining Engineer, Radcliffe, Acklington, Northumberland.

Mr. ROBERT JOHN BROWN, Colliery Manager, Barakar, East India Railway, Bengal, India.

Mr. JOHN CURRY, Colliery Engineer, Rainton Colliery, Fence Houses.

Mr. PETER HARLE, Assistant Manager, Page Bank Colliery, Co. Durham.

Mr. ROBERT THOMAS MOORE, Civil and Mining Engineer, 156, St. Vincent Street, Glasgow.

Mr. WM. MORRIS, Jun., Colliery Manager, Waldridge Colliery, Chester-le-Street.

Mr. JAMES LESLIE SHAW, Civil and Mining Engineer, Somerset House, Whitehaven.

ASSOCIATE MEMBERS—

Rev. G. M. CAPELL, Passenham Rectory, Stony Stratford.

Mr. GEORGE ELLIOT COXON, Explosive Agent, Low Fell, Gateshead-upon-Tyne.

Mr. GEORGE HUMPHREYS-DAVIES, F.S.I., Surveyor, Valuer, and Rating Expert, 8, Laurence Pountney Hill, Cannon Street, London, E.C., and 16, Deansgate, Manchester.

ASSOCIATE—

Mr. EDWARD CHARLTON SCOTT, Surveyor, Rainton Colliery, Fence Houses.

STUDENTS—

Mr. ROBERT O. BROWN, Mining Student, Elswick Collieries, Newcastle-upon Tyne.

Mr. FRED. KING, Mining Student, Cramlington Colliery, R.S.O., Northumber land.

SUBSCRIBING COLLIERIES—

BUTTERKNOWLE COAL COMPANY, LIMITED, Darlington.
COWPEN COAL COMPANY, LIMITED, Newcastle-upon-Tyne.
ELSWICK COAL COMPANY, LIMITED, Newcastle-upon-Tyne.
WESTPORT COAL COMPANY, Dunedin, New Zealand.

The following gentlemen were nominated for election :—

HONORARY MEMBER—

Prof. HENRY STROUD, D.Sc., Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

Mr. ALEXANDER MATHIESON, Colliery Manager, Hetton Colliery, Carrington, near Newcastle, New South Wales.

Mr. CLAYTON E. J. MITCHELL, Civil Engineer, 27, Mosley Street, Newcastle-upon-Tyne.

Mr. JAMES NEWTON, Colliery Manager, Whitehaven Colliery, Whitehaven.

Mr. GEORGE OLDHAM, Engineer, 25, Western Hill, Durham.

Mr. T. A. TATE, Colliery Manager, Bunker Hill, Fence Houses.

ASSOCIATE MEMBERS—

Mr. GEORGE BLAXLAND ATKINSON, Timber Merchant, Maritime Buildings, Quay, Newcastle-upon-Tyne.

Mr. J. P. CORNETT, Managing Director, Ford Paper Works, Hylton, Sunderland.

Mr. ARTHUR PATRICK DODDS, Iron Merchant, 13, Dean Street, Newcastle-upon-Tyne.

Mr. CLAUDE BOWES PALMER, Assistant Colliery Manager, Usworth Colliery, Washington, R.S.O.

ASSOCIATES—

Mr. THOMAS BERRY, Overman, Bagnall's Houses, Swalwell, R.S.O.

Mr. ROBERT CARR, Under Manager, Usworth Colliery, Washington, R.S.O.

Mr. WILLIAM SEVERS, Under Manager, Beamish View, *via* Chester-le-Street.

STUDENTS—

Mr. WILLIAM HENRY MASCALL, Mining Student, 27, South Church Lane, Bishop Auckland.

Mr. GEORGE WALL, Mining Student, South Church, Bishop Auckland.

DISCUSSION ON MR. W. J. ORSMAN'S "NOTES ON THE PRODUCTS AND TEMPERATURE OF DETONATION OF SOME HIGH EXPLOSIVES."

Mr. SAVILLE SHAW said the first point he desired to draw attention to was with reference to the products of detonation of roburite. In view of the interest which had lately been taken in the products of its explosion it would have been of advantage if the paper had given more detail as to the methods of collecting, measuring, and especially of analysing the gases evolved. It would be remembered that roburite was a mixture of dinitro-chloro-benzene with nitrate of ammonia, and when this was detonated they got as the products—carbon dioxide, nitrogen, steam, and hydrochloric acid; this was according to the theoretical equation. It was stated in the paper that "the presence of the chlorine compounds in the ultimate gaseous products tends to still further reduce the effect of the escaping heated gases." He would have liked Mr. Orsman's explanation on this point. The mean of twelve experiments showing what the ultimate gaseous products were proved them to consist exclusively of carbon dioxide and nitrogen (carbon dioxide 32 per cent. + nitrogen 68 per cent. = 100) thus allowing nothing whatever for the chlorine compounds referred to. If these compounds were present how was it that they were entirely overlooked in the analyses? Another point which was of interest to chemists was in regard to the volume of the evolved gases. In the paper 10 grammes of roburite were said to give 4,780 cubic centimetres of gas, but it was quite impossible to obtain such a large amount of gas from that quantity of roburite; the largest calculated proportion being 3,496 cubic centimetres. With roburite of the composition given by Mr. Orsman, 10 grammes would contain 8·6 grammes of nitrate of ammonia and 1·4 grammes of dinitro-chloro-benzene. If the whole of the nitrogen in the nitrate of ammonia were converted into free gas it would occupy 2,408 cubic centimetres at 32 degs. Fahr., and this amount added to the nitrogen from the dinitro-chloro-benzene, viz., 154·8 cubic centimetres, gives a total possible volume of gaseous nitrogen of 2,562·8 cubic centimetres. Similarly, the amount of dinitro-chloro-benzene used contains ·5 gramme of carbon, which converted into carbon dioxide would furnish 933·3 cubic centimetres of that gas. This volume added to that of the nitrogen gives the total amount of the two gases as 3,496·1 cubic centimetres as against the 4,780 cubic centimetres found by Mr. Orsman. Even if the evolved

gases had been measured at 59 degs. Fahr. instead of being reduced to 32 degs. Fahr. their volume would only be raised to about 3,688 cubic centimetres, and if the gas from the detonator, containing 15 grains of fulminate, were added to that, the total calculated volume would still be below 4,000 cubic centimetres. This error of something like 25 per cent. was somewhat important, considering the nature of the substances dealt with. No doubt the writer had some simple explanation of the apparent discrepancy, but at present he (Mr. Shaw) was quite at a loss to account for it.

Mr. Wm. Jas. Orsman, in reply, wrote that full details were given in the paper as to the methods of detonating the explosives and collecting the resultant gases. Having obtained these gases, bottled up in a cylinder, it was very easy to determine their composition by the ordinary laboratory methods. The chlorine present in the dinitro-chloro-benzene combines with the hydrogen to form hydrochloric acid, which exists as gas when the shot is fired, but on the cooling of the gases separates out with the condensed water vapour and collects at the bottom of the cylinder. As the analyses of the gases were made at the ordinary temperature, and were meant to show what products actually escaped into the air of a mine, no notice was taken of the amount of hydrochloric acid and water vapour formed. Similarly, no deduction was made for the volume of gas formed from the burning of the detonator fittings, which consist of paper and marine glue, and weigh between 2 and 3 grammes. No claim is made to give an exact analysis of the products from the explosives themselves, but to get a general idea of the nature of the gases formed when such explosives are in actual use down a pit. The principal aim of the whole series of experiments was to establish the fact that such attempts to lower the temperature of detonation of nitro-glycerine mixtures by the addition of carbonaceous matter, as in carbonite, means the production of the poisonous gas, carbon monoxide. With roburite, on the other hand, which contains an excess of nitrate of ammonia, no carbon monoxide is formed, and any further addition of nitrate of ammonia would only tend to still further lower the temperature of detonation.

The discussion then closed.

DISCUSSION UPON MR. HENRY PALMER'S "NOTES ON AN ELECTRIC TRANSMISSION PLANT AT EAST HOWLE COLLIERY," AND MR. D. SELBY BIGGE'S PAPER ON "THE PRACTICAL TRANSMISSION OF POWER BY MEANS OF ELECTRICITY, AND ITS APPLICATION TO MINING OPERATIONS."

Mr. SYDNEY F. WALKER (Cardiff) wrote that a great many of the remarks he had made in the discussion upon Mr. Snell's paper* were equally applicable to Mr. Palmer's paper. The writer's objections, for instance, to the use of old wire-rope as either lead or return cable applied with their full force here, and in addition he noticed that Mr. Palmer had experienced some difficulty with the electrical resistance offered by the old wire-rope. This was a very important point, which should receive careful consideration. If many of the wires of the rope were broken, as the writer thought would naturally be the case before the rope was abandoned for mechanical purposes, the measured electrical resistance would be very much higher than the dimensions and weight would point to, as the continuity of each wire, or of a very large number of them, being broken, conduction through the mass of the rope would take place very largely across the oxidized surfaces of these wires, and such surface contacts always have a very high resistance. In addition to this, if it had been necessary to joint two pieces of old wire-rope together, the joint itself would add considerably to the resistance offered. The writer believed that if all items of cost were carefully reckoned it would be found cheaper to use two insulated copper cables than to use old wire-ropes for the return. As the writer pointed out in the discussion on Mr. Snell's paper, he did not like making the whole mine part of the circuit, as would be done if a naked return was used for any voltage that can be utilized either for lighting or power. The writer was not surprised therefore to find how great was the loss between the generator and the motor. No doubt a large part was due to the old iron wire-rope. The writer noted also that the actual return in work done, water raised, of the indicated horse-power in the driving engine was the lowest on record. This appeared to be due very largely to the small pipes that were used, but it showed how necessary it was to have all the factors before judging of the relative efficiencies of any two methods of transmission. It by no means followed, however, that because there was a heavy loss both in the cables and in the water-pipes

* *Trans. Fed. Inst.*, vol. ii., page 150.

that Mr. Palmer did wrong in adopting electricity, or even that he was working extravagantly. This question could only be decided by placing the cost of the additional horse-power which had to be furnished against the interest of the additional outlay on cables and water-pipes that would have been necessary to avoid these losses. One point appeared to the writer to come out very strongly in Mr. Palmer's paper, viz., the great convenience which attended the use of the electric method of transmission, and the speed at which the apparatus could be erected. This was always worth money, and had done more and would do more to spread the use of electrical apparatus of all kinds than any other quality it possessed.

Mr. SYDNEY F. WALKER (Cardiff) wrote respecting Mr. Bigge's paper that he had not much to add to his remarks upon Mr. Snell's and Mr. Palmer's papers. As already mentioned, he did not think that the plan of enclosing the commutator within a gas-tight box, or of placing the brushes inside the commutator, was likely to prove more than a temporary expedient. The covers in either case would not remain gas-tight after being in use for some time, while the inconvenience of the arrangement was likely to give trouble. The best remedy for the danger of igniting gas from the sparks at the commutator of any dynamo would be the reduction of the spark below firing point rather than the enclosure of the commutator or of the brushes. It was now well understood that it was not a spark *per se*—any spark—that would ignite an inflammable mixture, but a spark which contained a certain definite quantity of electrical energy. This quantity appeared to be at least 20 watts, as far as experiments and observation have enabled the writer to determine, or one-third of the energy at present employed in a 16 candle-power incandescent lamps; consequently where it is necessary to use an electromotor in a gaseous atmosphere the motor should be so constructed as never to give rise to sparks having this amount of energy, under any possible conditions. This is perfectly practicable, at a cost not greatly exceeding that involved in making the armature gas-tight. Professor Silvanus Thompson found that blue sparks did not ignite gas; and Mr. Snell found that unless the copper of the commutator or brushes was heated to a certain degree gas could not be ignited. The writer's own experiments, carried out some years ago, and repeatedly confirmed, show that an electromotive force of at least 2 volts must be present across the gap over which the spark leaps, and that when the voltage is at this low figure the current passing in the spark—it is a true electric current, just as that which furnishes the arc lamp is—should be not less than 10 ampères. When the current is used to generate heat in a wire, according to the

writer's experiments, the wire must be quite yellow before it will ignite gas, if present. The time factor, of course, must be considered in this matter, as in all other engineering problems. Where the sparking is continuous, and the surrounding conditions are such that the atmosphere in the immediate neighbourhood of the commutator rises in temperature, it may ignite in time if the atmosphere is inflammable. But such conditions can never be present where a motor is used. It may be assumed that even at the face of the coal only occasional outbursts of gas are to be feared, which will be quickly diluted below the dangerous point by the ventilating air-current, so that the dangerous mixture could never remain long enough in the neighbourhood of the commutator to be heated in the manner described. Further, the revolution of the armature itself must and does create convection air-currents which would produce the same result. An interesting point here arises: suppose that a gaseous mixture be inadvertently enclosed within the cover of the commutator, would not this tend to become heated to the dangerous point, merely from the fact of its enclosure, notwithstanding the convection currents set up by the revolving armature? With reference to the question of sparking across the break when a cable is sheared by a fall of roof, the writer certainly admires the ingenuity with which the inventors, the Messrs. Atkinson, have worked out their non-sparking cable. He was present at Prof. Silvanus Thompson's lecture at Cardiff, last year, when he exhibited the Atkinson cable; it behaved perfectly when broken, there was no spark at the break, and the lead fuze behaved as it was wanted to, but when he proceeded to handle the cable again there was a spark between the broken ends of the cable, or between one end of the main cable and the central wire. As far as he remembered, Mr. Atkinson's explanation of this was quite correct, viz., that an accidental connexion was made. But the question arises: might not this same accidental connexion, or something similar, take place in the mine? It must be remembered that the main cable remains connected to one terminal of the dynamo, while the inner safety wire remains connected, through the motor or lamps, to the other terminal of the dynamo, so that should the break of the main cable be a jagged one, as may easily be, a fresh connexion and a fresh break may occur, giving rise to a spark. There is also the possibility of the wire fuze not acting; fusible cut-outs are unfortunately not reliable. The passage of the current through them, and the vibrations of the building where they are situated, tend to make them brittle, and cause them to "go" when they are not wanted. In order to avoid this, it is necessary to have the fuze wire stronger than otherwise would be necessary, so that it may not

be a constant source of trouble; and this results in the fuze taking a long time to melt if it happens to be nearly new when called upon to act. In the writer's opinion if this cable is used, an electro-magnetic automatic cut-out should be employed in place of the fusible cut-out, and some such device as that shown in Fig. 1 should be inserted in the circuit of the main cable, so as to break the connexion with the dynamo immediately the cable is sheared underground. The idea of the apparatus is as follows:—A bent lever A, one arm of which forms a counterbalance weight, and the other carries a contact piece C, is inserted in the circuit; the mercury cup B, into which the contact piece C dips, being also part of the circuit. Where the current to be controlled is large, there are two contact pieces dipping into two mercury cups. The coils of the electro-magnet D are also in the same circuit, that of the cable to be cut off from the dynamo. A second lever E, with one arm very much longer and heavier than the other, engages with the toe-piece of the contact lever C, and its lighter arm carries an iron armature F, which faces the pole of the electro-magnet. The current, when the circuit is complete, passes from the dynamo round the coils of the electro-magnet D, thence to the mercury cup B, from there to the lever C and to the pivot or second mercury cup as arranged, and so on to the cable. As long as the current is passing round the electro-magnet the light end F of the lever is held down by the attraction of the pole of the electro-magnet for its armature, and the contact piece is free to rest in the mercury cup. The counterbalance A is also then acting by its weight to keep the contact piece C firmly in the mercury cup B. On the cable being broken below, the current ceases round the electro-magnet coils D, the armature F is released, and the weight of the opposite arm of the armature lever E causes the end next the contact piece to cant sharply upwards, knocking the toe of the contact lever up, and throwing the counterbalance A to the other side of the vertical line passing through its pivot. The contact lever revolves on its pivot, the counterbalance falling backwards, thereby breaking the circuit. In Fig. 2 is shown the electro-magnetic automatic cut-out which the writer has designed for use with electric lights and power circuits in mines. The arrangement is similar to that of the circuit breaker already described, but the office of the electro-magnet D is

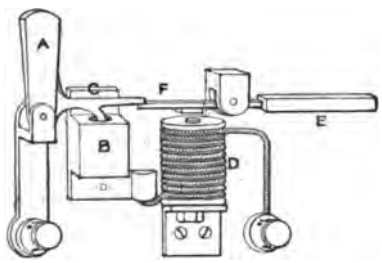


Fig. 1.

now to break the circuit on the arrival of a current whose strength is above a certain figure. The armature lever F in this apparatus has its two arms almost equal, the balance being on the side of the one E, which acts as a tripper. The armature is on that arm of the lever away from the contact lever, as shown, where it is faced by the pole of the electro-magnet. The current passes, as in the other apparatus, through the coils of the electro-magnet D to the mercury cup B, thence to the contact lever, and so on. When at rest, that is to say when the circuit is complete, the contact piece C rests in the mercury cup B, and the weight of the counterbalance F tends to keep it there. On the arrival of a current of the strength for which the apparatus is set, the armature F is pulled very sharply towards the pole of the electro-magnet D, carrying with it that arm of the lever. The opposite arm E of the lever gives a sharp cant to the contact lever C, which falls over, breaking circuit as before. The writer has also arranged the apparatus to work with an excess electro-motive force, and to complete a second circuit after breaking the ordinary working circuit if required. This apparatus acts with great promptness in such a case as the accidental contact of two wires connected to opposite sides of the dynamo; so quickly, indeed, that if, as often happens, a wire touches another and is drawn away, the spark between the two surfaces is very small indeed, though an ampère meter shows the passage of a very powerful current while the contact lasts. Electro-magnetic automatic cut-outs for use in case of short circuit, or over-running, if carefully employed, are of great service; but he does not recommend the use of the other apparatus except in special cases, as it tends to add to the complications at the switch board. He does not like fusible cut-outs, and only uses them in very special cases. The cable itself should be made strong enough to stand the shearing strains brought by heavy falls of roof, but the additional strength required for this purpose, over and above that of the cable as it would be turned out in the ordinary way, should be given by means of several longitudinal wrappings of some fibrous insulating substance, such as jute. The necessary strength can be thus obtained, and freedom from sparking thereby avoided at a very considerably less cost than would be incurred in the special form of cable designed by the Messrs. Atkinson, or in any external wire armour. Though steel and

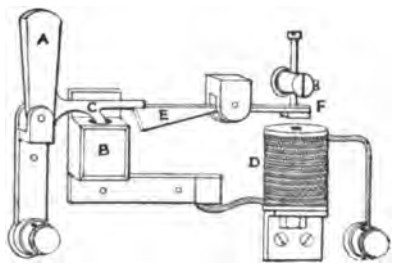


Fig. 2.

iron have very properly taken the place of hemp for ropes that are used both in mines and ships, it is mainly because they wear better and occupy a smaller space. But a cable for electric light or power has no appreciable wear, the additional space occupied by the jute wrappings are no inconvenience, and on the other hand the cable so made is handier in every respect. It is more flexible, more easily laid, and more easily jointed. Further, there is every chance of a cable so made stretching sufficiently, under a very heavy fall to avoid fracture. We are apt to forget that hemp has great mechanical strength if there is only plenty of it.

Mr. C. C. LEACH (Seghill) said an electric pumping-plant had recently been put down at Seghill colliery. It is driven by a Robey vertical engine with a cylinder 9½ inches in diameter and 9 inches stroke, fitted with a Pickering governor. It is intended to work at 100 lbs. per square inch, although at present the governor reduces the steam down to 39 lbs. The fly-wheel, which acts as the belt pulley, is 3 feet 6 inches in diameter. A link leather belt, 6 inches wide and ½ inch thick, is used to drive with 13 feet centres. The Goolden dynamo is intended to produce 24 ampères, at 460 volts, when running at 780 revolutions per minute. It is fitted with a pulley 10 inches in diameter, and is said to produce 15 horse-power. The cables are, in all, 3,160 yards long of 7/16 copper, rubber-insulated; this length of cable is used for the distance from the dynamo at bank to the motor down the pit and back to the dynamo. The 11 horse-power motor is of the Goolden gas-tight pattern, equal to an output of 24 ampères at 400 volts when running at 1,050 revolutions per minute. The pump has three single-acting rams of 5½ inches diameter and 9 inches stroke, geared down by double helical teeth in the ratio of 24·87 to 1. The vertical head or lift from the water-edge to the delivery is at present 121·88 feet. The single suction-pipe is 31 yards long, 11·54 feet head, and 4 inches diameter, with faced joints. The rising main consists of two pipes, 4 inches in diameter, each 886 yards long, with 110·34 feet head, making a total length of 917 yards of pipes from the water-edge to the delivery. The following tests have been made of the plant :—

Observations.	Sept. 14, 1892. Average of Seven Tests.	Sept. 23, 1892. Average of Seven Tests.
Indicated power of engine	10·65 horse-power	... 12·40 horse-power
Water pumped per minute (measured)	80·38 gallons	... 90·08 gallons
Power in water pumped (including friction of pipes)	3·39 horse-power	... 4·00 horse-power
Useful effect	31·88 per cent.	... 32·25 per cent.
Engine, number of revolutions per minute	190	... 204·5

Observations.	Sept. 14, 1892. Average of Seven Tests.	Sept. 23, 1892. Average of Seven Tests
Dynamo, volts	408	456·3
" ampères	14·1	14·2
" output	7·74 horse-power	8·68 horse-power
Loss in engine and dynamo	27·73 per cent.	30·00 per cent.
Pump, revolutions per minute	42	47·43
Pressure of rising pipes	50·5 pounds	53·20 pounds
" of suction-pipes	10 "	10·40 "
" of pipes, pump standing ...	42 "	42 "
Friction of engine-belt and dynamo at 206 revolutions per minute, brushes on		4·17 horse-power
Friction of engine-belt and dynamo at 200 revolutions per minute, brushes taken off		3·32 "
Friction of engine alone, without the belt		2·24 "
Per cent. of horse-power to drive above (engine, belts, and dynamo) ...		33·64
Pumps' displacement per minute ...	97·17 gallons	109·73 gallons
Slip in pump	17·27 per cent.	17·90 per cent.
Motor, revolutions per minute... ...	1,044	1,180
Dynamo, revolutions calculated from engine revolutions		859
Rising main head due to pressure ...		95 ft. standing
Suction-vacuum head due to suck of 10·40 feet		24 ft. running

Mr. G. B. FORSTER asked if the water was measured?

Mr. LEACH said it was, and in both tests the observations were continued simultaneously every tenth minute for an hour, and the average of the seven taken. The pressure of the water against the rams was taken by an indicator, screwed into the rising main, and the suck or pull of the pump by screwing it into the suction-pipes, and pulling the indicator barrel round by hand slowly when pressing the pencil against the card.

Mr. A. L. STEAVENSON (Durham) said a reference to Mr. Palmer's paper* gave his statement that "rightly or wrongly, from the experience acquired in experimenting with this plant, the writer is strongly of the opinion that, owing to the extremely diversified conditions which are met with in the various electric pumping arrangements, particulars of which are before the public, it is quite impossible to base any reliable conclusions upon the so-called plant-efficiency of the various installations." But they had never heard of this when talking of compressed air or ropes. It was only when electrical plant was brought into consideration that they were told it was impossible to arrive at real results. He (Mr. Steavenson) would like to draw attention to page 286,† where Mr. Selby Bigge said

* *Trans. Fed. Inst.*, vol. iii., page 276. † *Ibid.*, vol. iii.

"the calculation therefore of the power wasted in transmitting power by means of electricity is extremely simple, and the efficiencies of a plant can be readily foretold," etc. Mr. Selby Bigge did not appear to agree with Mr. Palmer, and where doctors differed others might take their own view of the matter. His own view was that if the same principles were applied in obtaining the useful effect, that compressed air would compare favourably with electricity. Mr. Palmer wished to take the brake-power—the power simply after it passed out of the motor! Decidedly not! because they were there losing the very essence of the electric arrangement, and that essence was, if they had a motor running at 1,100 or 1,200 revolutions per minute and pumps only at 15 or 20 revolutions they could not reduce the speed of the motor from 1,200 to the pump at 20, without losing a large amount of power. He had tried with all sorts of engines, and he knew that gearing which was a necessary part of electrical work was very destructive of power, and it was here that the chief loss occurred. In one of Mr. Palmer's plants he reduced his power $42\frac{2}{3}$ times. This was where the loss came in. He did not mean to say they could not transmit the power between the dynamo and the motor with only a small loss; he would grant 90 or 95 per cent. of efficiency. The power was in the motor as the Irishman's purse was in the sea. On the same principle he supposed they would contend it was not lost because they knew where it was, but still they could not use it. He understood Mr. Leach's practical results amounted to this: That there was nothing very encouraging in using electricity as compared with other motive powers. Had he (Mr. Steavenson) been in Mr. Palmer's place and been asked to put down a plant under the same conditions he would no doubt have adopted electricity, as the distance was very great, and the cables could be moved about very readily. If it were not for the danger of electricity in the face, where they had to use safety-lamps, it would, he thought, be the very best motive power there; but where safety-lamps were necessary it required careful consideration as to whether that was a safe place for a motor. There was one thing in favour of compressed air: it was very pleasant and beneficial in the close atmosphere of a mine; they should not forget this desirable feature when considering the advantages of compressed air.

Mr. Thos. E. Forster (Newcastle-upon-Tyne) said he had had a short experience of electric pumping-plant at North Seaton colliery. It had not been running long enough to make tests such as those submitted by Mr. Leach, but it had otherwise given every satisfaction. The pump was delivering about 250 gallons of water per minute; the distance from the dynamo to the motor was about 2,700 yards, including the depth of

the shaft, as the dynamo was placed on the surface. The water was lifted about 50 feet, and passed through about 1,300 yards of 8 inches pipes. In connexion with this installation there was perhaps only one innovation, and that was in regard to laying the concentric cables. These had been placed underground, except in one or two places where the ground was wet, where they were enclosed in wooden boxes. He thought this arrangement rendered the cable safer, especially in cases like theirs, in which the cables had to be taken down a heavily timbered road, driven through old pillars. It was almost impossible to prevent the wires being disturbed where there were many repairs to be done. He quite agreed with Mr. Palmer's remarks as to the difficulty of recording the efficiency of these experiments, but according to Mr. Steavenson's remarks it was not fair to compare the results with those of compressed air unless they had some direct means of comparison. He would be very glad to communicate to the Institute the results of any tests which they might make at North Seaton colliery.

Mr. T. O. Robson (Gateshead-upon-Tyne) thought there might be a little misapprehension, but he understood Mr. Forster to say that burying the cable and taking it through boxes where the strata were wet would do away to a large extent with the necessity for safety-cables.

Mr. T. E. Forster said that where the cables were not buried they were temporarily raised and placed in boxes to keep them dry. Where they were buried there could be no danger arising from falls of stone, etc. Of course the cables were waterproofed, but it was thought best to keep them dry.

The President remarked that the cables would, of course, be perfectly safe as long as they were not broken.

Mr. T. E. Forster replied that he did not think they could easily be broken when placed underground.

Mr. G. S. Corlett (Wigan) said that as he had been responsible for the electrical portion of the plant described by Mr. Palmer he would like to make a few observations on it. With reference to the resistance of the old wire-rope, Mr. Walker was right, although for economy it was tempting to use old wire-ropes. The consideration of economy in first cost induced them to use wire-rope at East Howle colliery. They had had considerable difficulty with the connexions, and some portions of the wire-rope itself offered a higher electrical resistance than others, so that there was a consequent amount of loss. The electric plant was put down as the cheapest and speediest way of dealing with the water at the colliery and not with the view of publishing interesting results. High

efficiency was about the last thing considered. The steam was obtained from boilers heated by the waste gases of the coke ovens, so that a few horse-power of steam wasted was of no great moment, especially as the pumping was done at night, when there was a large quantity of spare steam. The only question considered was to keep the cost down as low as possible. He was not at all sure that Mr. Walker was right in saying that this plant had the lowest efficiency on record. The term "plant-efficiency" was a very misleading one, and it would hardly be fair to compare the plant-efficiency at East Howle colliery (from the plant-efficiency point of view) with the results that might be obtained with a plant like that Mr. Leach referred to. He claimed, however, that they were doing more work at East Howle colliery, although the theoretical power in the water itself might not show it; he contended that they were dealing with a larger quantity of water than had been attempted elsewhere in this country, and, taking into consideration the efficiency of the transmission, they were getting very satisfactory results. The plant was originally laid out to deal with 500 or 600 gallons of water per minute; now they got 900 gallons, and shortly the plant would be dealing with 1,600 gallons per minute. With regard to the loss of power in gearing, results differed considerably, but he thought, if the gearing were properly designed, this was not a serious matter. In a small pumping set which was put to work the previous week, he had found by careful measurement that the power absorbed by the motor when driving the pump at its normal speed was only 0·3 electric horse-power; the pump was a three-throw one, with 3½ inches rams, making 30 revolutions per minute, driven by a Crompton electric motor running at 1,200 revolutions per minute. The pump and motor are fixed on the same bed-plate, connected by two sets of double helical gearing. He contended that the loss of only 0·3 electric horse-power in the motor, gearing, and pump friction was a very satisfactory result. Mr. Forster's plant might possibly be the largest pump in the kingdom, but it was only pumping 250 gallons per minute as compared with 900 gallons per minute at East Howle colliery. He would like to know, with so large a pump as that at North Seaton colliery, what was the loss in running the pump when empty? He might remark that in the electric pumping and hauling-plants working in South Wales it was the common custom to use a very heavily armoured cable and to bury it in about 6 inches of dirt.

Mr. A. L. Steavenson suggested that where electricity was adopted as a means of transmitting power they should adopt the centrifugal pump, and avoid the use of gearing when the height of column permitted.

Mr. LEACH said electricians always raised the question of the size of the water-pipe; this had nothing to do with the efficiency or useful effect. With regard to the use of centrifugal pumps he had asked tenders for one to assist a syphon which had been troublesome.

Mr. W. C. MOUNTAIN (Newcastle-upon-Tyne) said he thought that the North Seaton pumping-plant was the largest in the kingdom, so far as the pumps were concerned, the rams being 9 inches in diameter and 15 inches stroke. The question of reducing the speed of the motor to that of the pump—from 720 revolutions to 30—was a serious one to deal with. There were several ways of doing it: the first by ordinary spur-gearing; next by worm-gearing; and thirdly by belts and other combinations. Worm-gearing was adopted for the North Seaton plant owing to want of space. The worm-wheel was made of phosphor-bronze, and the gearing perfectly true. It was pumping over 250 gallons of water per minute against a head of 50 feet, and the dynamo produced approximately 10 electrical horse-power. He would like to know how Mr. Palmer reduced the speed, and how Mr. Selby Bigge found spur-gearing to work at the high speed at which it had been running? With regard to the cables at North Seaton colliery they were placed underground at his suggestion. He had seen several of the so-called safety-cables, and if any of the members had any experience of these he would like to know how they behaved in practice. His own impression was that they could not avoid a certain amount of sparking, and probably they would not always act at the right moment. It seemed a pity to use a cheap cable simply because it reduced the cost; in a case of this kind people should be disposed to spend a little money in the first instance to put down a thoroughly reliable plant. In regard to the efficiency of the North Seaton electric pumps it was only fair to say that in a small engine such as Mr. Leach used the efficiency could not be very high, and it would be better to take the electrical efficiency of the plant itself.

Mr. LEACH said he was not able to give the power going into the motor, as they had not a voltmeter. The 2·24 horse-power used to drive the engine alone amounted to 18·06 per cent., and although that was rather high it would be equally so with compressed air or any other plant. They could not discard the engine, seeing it was the motor power whether using electricity or air or anything else.

Mr. M. WALTON BROWN asked whether the use of safety-cables was necessary? If they were efficient there were still other parts of the plant which might become heated, such as the resistance-frames, etc. If Mr.

Mountain or Mr. Forster had made any test, he would like to know whether the insulation of the cable had been maintained as good as when the plant was erected?

Mr. MOUNTAIN said the cables at North Seaton colliery were concentric, insulated with bituminized fibre, and finally drawn into lead piping. They were then braided outside and covered with bitumen, so that it was almost impossible for the wet to destroy the insulation.

Mr. T. E. FORSTER said that at North Seaton colliery the cables were only buried where the ground was dry.

Mr. MOUNTAIN said the cable had only been laid about three months, and it was hardly fair to take a resistance test at present.

Mr. WALTON BROWN suggested that the Atkinson cable at Newbottle collieries might be tested by trying the effect of breaking the cable in the engine-house at bank when the full load was on.

Mr. LEACH remarked that each switch was in a gas-tight case.

Mr. W. C. BLACKETT (Durham) said there had been no cases brought before the Institute in which the so-called safety and other cables had been tested in a practical way. In answer to a question he had put at a previous meeting one gentleman admitted that non-sparking was not in accordance with theory, and the claim that they did not spark in use was based upon laboratory experiment only. He (Mr. Blackett) was not an electrician, but looking at the matter from a common-sense point of view he failed to see how they could break a wire without getting a spark. As regards the lead-covered cable he would have liked to hear the result of actual experience. He had a small experience—scarcely worth mentioning—in conjunction with the more important plants described. In lighting a pit 100 fathoms deep, he had been obliged to use a bitumen-covered cable after the failure of two lead-covered ones. The first lead-covered cable failed in a very short time; the pit was wet, the lead seemed to be eaten away at once, and the current leaked into the brickwork of the shaft. The makers said they could supply a better lead-covered cable, and it was tried, but the result was the same as before.

Mr. T. E. FORSTER asked if the cables were covered with anything besides lead?

Mr. BLACKETT replied that the first was simply lead-covered, the second had a bituminized cover over the lead. Insulators were used, but a distinct current could be felt by placing the hand on the brickwork in the shaft.

Mr. MOUNTAIN asked if the cables themselves were thoroughly insulated?

Mr. BLACKETT replied that they were bought as such.

Mr. MOUNTAIN—What was the insulation?

Mr. BLACKETT did not know.

Mr. MOUNTAIN could not understand if the pit water was pure water how it could affect the lead covering; of course a chemical action in the water might be the real cause of the mischief.

Mr. STRATTON thought the fact of feeling the shock through the brickwork proved defective insulation.

Mr. BLACKETT said of course that was what he complained of.

Mr. STRATTON meant that the cable might not have been carried down the shaft on proper insulators.

Mr. BLACKETT said the cable was insulated, but it was thought that the wet state of the shaft destroyed the effects of the insulators.

Mr. T. E. FORSTER suggested that a test of the water in the shaft might reveal something.

Mr. BLACKETT said the water had been analysed, but nothing of an injurious nature was discovered in it.

Mr. A. L. STEAVENSON said he understood it had been suggested that the loss of power at the engine should not be reckoned, but it was so when other systems were tested.

Mr. MOUNTAIN explained that his contention had been that as the efficiency of engines varied considerably—that of an engine running at 100 or 200 revolutions per minute being much higher than one running at 10 or 15 revolutions—this loss should not be debited to the electrical plant.

Mr. HENRY PALMER, replying to the discussion, said he agreed in the main with Mr. S. F. Walker's remarks as to the use of old wire-ropes; but, as Mr. Corlett had pointed out, the only reason for using wire-ropes was on the score of economy in first cost. He would say plainly that if he were again required to put down an electric plant, after the experience he had gained, he would not hesitate to put down a double insulated conductor. As he pointed out on page 273* the wire-rope was supplemented by copper wires in order to reduce the loss, which amounted to something like 200 volts out of 550. He did not think he had advocated the use of old wire-rope, for they had found it very unsatisfactory. Mr. Walker also referred to the small water-pipes, but as had been explained in the paper these were already in position, and rather than face an expenditure of about £800, they elected to put up with a certain loss of efficiency of which they were fully aware. With reference to Mr.

* *Trans. Fed. Inst.*, vol. iii.

Steavenson's remark as to plant-efficiency some little mistake seemed to have crept in; what he meant to convey was that nearly every plant differed from every other owing to local circumstances, and it seemed to him that for the purposes of comparison it was better to stop short at the work delivered on the pulley of the motor and ignore the work done in friction of water lifted, in comparing the efficiencies of electric plant. He gave the actual comparison of the work done in the water lifted compared with the indicated power of the engine, and the result to most people appeared low—16½ per cent. (Mr. Walker said the lowest on record.) He was not ashamed of the result, for it answered the purpose very well. The plant saved the pit from absolute drowning on three separate occasions, and they had every reason to be satisfied with the result. The plant-efficiency could have been made greater if they had gone to a higher first cost. He only contended for his own case; Mr. Steavenson seemed to think he proposed to extend it to other cases. It was hardly fair to compare the East Howle efficiency of 16·4 per cent. with that of North Seaton of 46 per cent. They should consider that in one case they were pumping 900 gallons through a 9 inches water-pipe, and in the other only 140 gallons through a 6 inches pipe. The question of gearing was a mechanical one, and there was a good deal in Mr. Steavenson's contention that they could not reduce from 1,100 to 40 revolutions without some loss in the gearing. This loss was, unfortunately, unavoidable in the present stage of their experience, and until they could devise some other arrangement of running motors at a lower speed or running plants coupled up direct, they would have to put up with it. No doubt in a few years' time they would have more knowledge and be able to put up more economical plant than at present. He had no knowledge of the use of electricity at the face; at present he had only put on record what they had done where employing naked lights, and until they had something more before them on the subject he would not care to go beyond this. He thought Mr. Mountain suggested the elimination of the engine, and starting with the power delivered into the dynamo at bank, and utilized in the water below. It did not much matter, however, which way it was taken, so long as it was understood; but the same might be urged in regard to the experiments made in past years on fans. He was glad to hear what Mr. Blackett said as to the lead-covered cable. It occurred to him that, say with buried cables on engine-planes, it was a frequent practice to take ballast and such like material to make the roadway, and if water accumulated this might produce an undesirable liquid to act upon the cable—something of the nature of sulphuric acid, which would speedily effect a great deal of harm. With reference to Mr.

Stratton's remarks on insulated wires, no matter how they insulated with the earthenware insulator, if the shaft was wet they would get leakage; he found this at once with their old ropes when he stood in a damp place. In conclusion, he now considered that the results of the test referred to on page 277 of his paper* should be summarized as follows:—

	Indicated Horse-power.	Percentage of Work.
Loss in engine	12·00	22·33
„ generator	3·62	6·73
„ cables	7·04	13·09
„ motors	3·36	6·25
„ pumps	5·34	9·93
„ pipe friction	13·60	25·30
Water lifted	8·80	16·37
	53·76	100·00

The two items of pipe friction and water lifted give, when added together, the useful effect of the plant, which was equal to 41·67 per cent. The details of the calculations of the pipe friction are:—

Length of Pipes. Yards.	Diameter of Pipes. Inches.	Water Pumped. Gallons.	Head of Water. Feet.
750 ...	9 ...	delivery, 880 =	40·4775
50 ...	9 ...	„ 440 =	·6745
50 ...	9 ...	suction, 440 =	·6745
132 ...	9 ...	„ 340 =	1·0626
200 ...	4 ...	„ 100 =	8·0200
	Total		50·9091

Or 51 feet of head due to pipe friction, equal to 13·60 horse-power.

Mr. D. Selby Bigge wrote in reply, referring to Mr. Leach's remarks and the particulars given of the tests which resulted in a useful effect of 32 per cent. being obtained with the Seghill plant, that the engine for driving the electric pumping plant was about three times larger than necessary, provision being made for driving an electric lighting dynamo as well. With a small head and large suction-pipes the slip in the pump would be very materially increased; and, taking the small size of the plant and other things into consideration, the result is very reasonable. With reference to Mr. A. L. Steavenson's remarks, the writer maintains that, provided all the conditions are given, the exact useful effect which will be obtained can be computed far more accurately in the case of electricity than for compressed air or any other means. It has been the writer's experience that one can predict with almost absolute exactitude the current required by a machine in order to do a given amount of work, the current being conveyed through any given length of cable of a

* *Trans. Fed. Inst.*, vol. iii.

section previously determined. Makers of electric power plants are prepared to guarantee within 5 per cent. the exact results they will obtain, a guarantee that makers of compressed air plants are not prepared to give. The loss in gearing should not exceed 10 per cent. if the gearing is accurately made and fitted. The writer would be very glad to hear what are the results which have been obtained by the electric pumping plant at North Seaton colliery, of which a few particulars were given by Mr. T. E. Forster. He does not think, however, that a very high efficiency will be obtained, as the head is small and the quantity of water pumped at present not very considerable; and he believes that the voltage adopted was low, not exceeding 300 volts. The writer can point out that no case of injury to persons has been recorded with pressures of 800 volts downwards; indeed, he can personally testify that he has received shocks of this pressure. The very obvious advantages derived from a small cable, the small currents to be handled, the great reduction in first cost, and the efficiency which is obtained, point to the desirability of using the highest possible voltage consistent with the safety of the workpeople employed. All cables are liable to damage from various causes; and the writer's view is, that that cable which is the most accessible to examination and repair is the best for use in mines, and a well insulated cable run on insulators is to be preferred to a buried cable. Mr. A. L. Steavenson suggests the use of centrifugal pumps in order to avoid the use of gearing: they are very suitable for small heads and large volumes of water, but electrical engineers are especially concerned in cases where considerable distances are involved and small volumes of water to be lifted great heights. Mr. Leach alleged that the size of the water-pipe had little effect upon the efficiency of the plant. The writer has found, by practical experience, that with heads of from 100 to 400 feet the pipe friction formed from 100 to 25 per cent. of the total work, and that the average friction in colliery pipes was from three to five times as great as that given by the highest of recognized rules and tables. The writer's firm had found that, except in the case of very low heads, worm-gearing was inadmissible owing to the great loss of power by friction, particularly when the worm-gearing became somewhat worn. He agreed with Mr. Mountain in saying it would be better to take the electrical efficiency of the plant at Seghill, owing to the smallness of the motor engine. The writer, however, hopes shortly to lay before the members of the Institute a series of complete tests made on electric power plants varying in size from 5 to 300 horse-power.

The PRESIDENT thought the discussion on these papers must now be

closed, though he felt sure they would still hear much on the same subject. Electric transmission was in its infancy and it would be employed in many places where it was impossible to convey other power. It was a great addition to the power at the disposal of the mining engineer, and as time went on, and they got to know more about it, its efficiency would no doubt be much improved.

DISCUSSION UPON MR. J. L. SHAW'S PAPER ON "THE HÆMATITE ORES OF CUMBERLAND."

Mr. J. M. MAIN wrote that he had had over twenty years' experience in the working of iron ore in Cumberland, and had taken considerable interest in the various theories which had from time to time been propounded as to the mode of hæmatite deposition. With reference to this question, he would mention one or two prominent facts which had come under his observation, and which were altogether antagonistic to the explanation given by Mr. Shaw. Although there was much in the paper open to criticism, he would confine himself at present to the remarks bearing directly on the mode of deposition. In dealing with this part of the subject, Mr. Shaw mentioned that it was a simple matter to account for the support of the roofs of the supposed caverns before they were filled with iron ore. His remarks on this point were certainly curt and vague. He says* "It is known that there are many points of support, in addition to the rock at the outer run or edge of the deposit, where the roof stone meets the sole without any intervening ore. One of these points is shown in the section (Fig. 3, Plate XXXVII.) across the Hodbarrow mines. The overlying limestone must have been steadied in this way, and if at any point the limestone was not supported, and fell upon the sole before the deposition of the ore took place, then at that point the ore would not be deposited. The above remarks especially apply to the iron ore mines in the Egremont district." An explanation of this kind, to be consistent, must apply not merely to a particular part of a district but to the whole field. The writer is acquainted with several large deposits scattered over the hæmatite-bearing measures of Cumberland, where the roof of the ore-bed, shelving off from faults, stretched at right angles from these faults to a distance of from 50 to 150 feet, the roof in some cases being limestone, with "pockets" of shale extending upwards for several feet, the limestone itself not being of that character which would support a superincumbent weight anything like so great as would prevail during the time

* *Trans. Fed. Inst.*, vol. iii., page 589.

the pre-existent caverns, described by Mr. Shaw, remained unfilled. In other cases the roof consisted of a shale-bed of a soft and brittle nature which could not possibly support its own weight, even if the space were only a tenth part of that indicated. These shale roofs are interbedded with the surrounding limestone. As an instance of the latter, the writer may mention the deposit of iron ore in the Crossfield Company's mines, extending from No. 7 pit westward to the main north-and-south fault, running through that portion of their estate; the lateral spread of the ore-bed was about 75 feet, while its longitudinal extension, embracing the above width, was 200 feet. The average thickness of the ore was about 9 feet, and that of the overlying shale 6 feet. Here and there, blocks of siliceous limestone occurred above the ore, but under the shale. These blocks when undermined had to be securely propped to prevent them falling. No stretch of the imagination could reconcile either of the above conditions with that part of Mr. Shaw's explanation contained in the paragraph above quoted. Another point, which seemingly had escaped Mr. Shaw's observation, but which had been prominently brought forward by Mr. J. D. Kendall in his paper on the "Hæmatite Deposits of West Cumberland," and which unquestionably was a clenching argument in favour of the displacement theory, was the fact of shale-beds extending not only across an ore deposit but into the limestone which formed the surrounding walls. Mr. Kendall, in his paper on the "Hæmatite Deposits of West Cumberland," gave a section showing the position of such a bed in the Crossfield Company's No. 8 opencast workings. The writer can testify to the accuracy of this section, as in several places the bed was followed for a considerable distance into the hanging wall. The ore at this part was from 20 or 30 feet from wall to wall, whilst its thickness both above and below the shale-bed was also considerable. This shale parting or bed must have existed before the ore was deposited, and must have remained suspended in empty space during the time Mr. Shaw's presupposed caverns were being filled with iron ore, by aqueous agency, from the bottom upwards, which is an utter impossibility. This fact was a complete proof that the hæmatite deposits in Cumberland were formed by replacement, as first suggested by Mr. Kendall, and demonstrated frequently by him with an array of facts and careful deductions, which, for completeness, have not been approached by any other writer. He (Mr. Main) had found a number of the fossils, common to the district limestone in the ore itself, the presence of which in such a position could not be explained in any other way than that advocated by Mr. Kendall.

Mr. J. D. KENDALL wrote in reply to the remarks of Mr. J. L. Shaw* on four points: firstly, as to the thin shales that are interbedded with the hæmatite and the surrounding limestone; secondly, as to the nature of the Gillfoot Park deposit; thirdly, as to the so-called limestone-bed in the breccia; and, fourthly, as to the quantity of calcareous matter contained in the thin ore-bed at Bigrigg. The writer put a number of questions to Mr. Shaw which that gentleman has not attempted to answer, nor shown that they were irrelevant to the points at issue. Surely it was incumbent upon him to do either one or other of these things, or to admit frankly that he could not. Even the latter course would have been much more satisfactory to members than a regalement of storyettes *apropos* of nothing. The writer did not, however, intend to let Mr. Shaw off in this easy manner, but again invited him to pursue one or other of the courses just indicated. If the explanation of that gentleman was worth anything at all surely it was worth defending and making intelligible. But to come to the particular questions that induced this communication, Mr. Shaw said,† he had been "employed twenty-two years in the iron-ore mines of Furness and Cumberland without seeing a bed or parting of shale running through a gut of ore and into the limestone on either side." This is not surprising when we remember how much people look at and never see, but in Mr. Shaw's case it was only what might be expected when it is known that his experience of the deposits mentioned by the writer as containing these interbedded shales is absolutely *nil*. A man might spend a hundred years in different ore deposits of this district and yet never see one of these shale partings, for the simple reason that there are only some deposits which contain them. They are never found in deposits in the first or second limestone of Cumberland, and very rarely indeed anywhere in Furness. But if Mr. Shaw's cavernous and sedimentary explanation be correct why should not these partings be found in all deposits alike? On the other hand if the deposits originated by replacement it would be useless looking for interbedded shales in deposits of the first and second limestone of Cumberland, because such shales do not exist in the limestone, nor are there many in the thick limestone of Furness. It is difficult, however, to rid one's self of the impression that Mr. Shaw had not been very anxious to find these shale partings, or it would have been a very easy matter for him to have asked the writer where any could be seen, which he never did. And now as to the nature of the Gillfoot Park deposit. Mr. Shaw says he "does not think that Mr. Kendall has had any previous

* *Trans. Fed. Inst.*, vol. iii., pages 601-603. † *Ibid.*, vol. iii., page 602.

acquaintance with this deposit, because he speaks only about the eastern side of the bed-like deposit being tilted, and takes no notice of the great downthrow fault on which the vein-like ore lies 900 feet to the west. Mr. Kendall is clearly in error, his sketch incorrect, and his idea of the beds being tilted is quite erroneous." In reply to the first part of this statement the writer would like to say that he is not in the habit of writing on subjects of which he has not had experience, and that not only has he had experience of the Gillfoot Park mines and the Whin Pit under the cemetery, but of every other deposit in the Whitehaven district and Furness. This is something doubtless outside Mr. Shaw's knowledge, but the writer hoped that that gentleman will not therefore treat it as apocryphal as he does the shale partings, simply because he knows nothing about them. Mr. Shaw surely cannot see the full force of the implication contained in his statement. Moreover, it is impossible to argue with anyone who assumes such a position as he had done. If he were to treat as apocryphal everything that he had not seen almost the entire universe would be to him but a fiction. As to the accuracy of the section of the rise part of Gillfoot Park mine, given by the writer, he can only at present re-affirm it, knowing that it represents substantially the facts. It can, however, easily be verified or disproved by going down the Whin Pit shaft, which was still open, and so doubtless was the drift therefrom, which cut through the red shales underlying the ore. This would involve some cost, but the writer was quite willing to bear that should his section be proved to be wrong (*i.e.*, if the beds be not tilted as he says), provided Mr. Shaw would take upon himself a similar responsibility in case the writer's section, on independent evidence, was found to be right. This seemed to be the only mode of settling the difference between us, otherwise affirmation and denial might go on interminably. Mr. Shaw's remarks about No. 4 Pit at Gillfoot Park, sinking through the so-called limestone-bed, did not affect the matter in dispute. The writer had seen several pits sunk through these limy bands, and the sinkers were invariably of opinion that they were going through a broken limestone-bed. In reality it was only a very limy part of the breccia. Mr. Shaw was under a misapprehension in supposing that anyone had indicated that he was not a theorist. However, it was highly satisfactory to know that his mind was strictly practical, for he would be the better able to deal with the following very practical question. If Gillfoot Park deposit was formed in a cavern, will Mr. Shaw say why the lessees have not been able to extract the ore worked by pits Nos. 1 and 2, and leave the original cavern intact? As a matter of fact the whole roof has collapsed, and settled down upon the

floor. The surface of the ground subsiding correspondingly. We feel very sure that if we were to fill up, say the Peak Cavern or Kent's Hole, or any other of the numerous caverns in the country, we could practically exhaust them again without injuring the strength of the roof in any way. And why? Because the span of the roof in every case is so small that there is abundant strength. The great downthrow fault which Mr. Shaw says the writer takes no notice of is actually shown in his (the writer's) section. Again Mr. Shaw writes "there is nothing in Mr. Kendall's remarks about there being calcareous rock in the ore-bed at Bigrigg; that is common enough. There is much less lime than sand in its composition, the stratum being composed of hæmatite, sandstone, and calcareous mudstone." To this the writer would reply that he does not believe there is a grain of sand in the bed. There is some re-deposited silica, but not much, whereas there are large portions of the bed almost entirely calcareous. But to settle the point the writer is prepared to have an independent analysis made on the terms mentioned above with regard to the testing of the facts at Gillfoot Park. Lastly, Mr. Shaw says the "growing together of hæmatite and limestone is wrongly expressed, and conveys a wrong meaning," but he does not tell us how to express the fact, nor what is the wrong meaning which it conveys. Will he kindly do so? The writer's chief anxiety is about the facts, and therefore he would most readily express any of them differently if by so doing they became more intelligible. This leads us to another remark of Mr. Shaw's that "the different classes of matter (in the ore) became ultimately separated by the affinity of particles." What does this mean?

Mr. J. L. SHAW, in reply, wrote that since replying to Mr. Kendall's first remarks he had carefully looked over the sections contained in that gentleman's paper on "The Hæmatite Deposits of West Cumberland," which show nothing against the idea of the deposition of ore in caverns, and the aqueous and chemical formation of hæmatite. The writer has given his opinion in regard to the Gillfoot Park deposit that "in this case at all events the cavern was excavated first and the ore deposited therein afterwards." Mr. Kendall assumes when he mentions a bed of shale running through a body of ore, and into the limestone on one or both sides, that it is necessary that the whole of the limestone which the ore has replaced should first have been carried away, according to the writer's theory above-named. But the writer did not convey that meaning; and it was not necessary that he should, while still retaining his opinion as to the ore having been deposited in caverns, because in many, if not in all cases, the wearing action on the

limestone, and the deposition of iron may have gone on simultaneously. Time is a very great element in the work of nature, so that while the limestone was being softened and worn by acidulated water (beginning of course at the point next the fault or joint to which the water had readiest access), at the same time and from the same water iron was being deposited. This process would go on until any shale-bed was reached, when a new bed would already have been formed for the shale to rest on, and it was not necessary that the water should have washed away the shale-bed, at all events in all cases, but that the same process should have gone on until the whole cavern was filled. There is not in any of Mr. Kendall's sections a case to which this method of formation would not apply. The writer had never seen the necessity of bringing in shale-beds to support his opinion on the formation of hæmatite, and he did not therefore think it necessary to ask Mr. Kendall where the shale-beds above referred to were to be seen, but was guided by the sections in Mr. Kendall's paper. Mr. Kendall looks at the matter from an entirely different standpoint, and it was not necessary therefore that the writer should see the relevancy of some of his questions, and as for opening out the Whin Pit again the proposal was not practicable, for the level, from the shaft at all events, had doubtless entirely collapsed. The writer's idea in regard to Mr. Kendall's Gillfoot Park section was that he depended upon his imagination when it was drawn. It was not even drawn to scale like the sections connected with Mr. Kendall's own papers. The writer was not therefore assuming too much when the idea entered his mind that he (Mr. Kendall) had "no previous acquaintance" with the Gillfoot Park deposit. He could not deny that the beds of limestone and shale on the hanging side of the vein under the cemetery were steeper than the general run of the bedding to the west of this fault, but he understood Mr. Kendall, by his statement of "the beds being tilted at a high angle by the fault A" to mean that the lying side had been forced up while the writer's idea was that the hanging side was thrown down. It might be said that there was practically no difference, but attention must again be called to the fact that Mr. Kendall in his first remarks said that the writer was "in error" in regard to the Gillfoot Park deposit in general, and to this point in particular. The writer did not depend on the testimony of the sinkers in regard to the bed of limestone mentioned as having been sunk through in the No. 4 Pit at Gillfoot Park, but on that of Mr. James Stout, the manager, who was of the same opinion. Touching Mr. Kendall's "very practical question" "will Mr. Shaw tell us why the Gillfoot Park lessees have not been able to extract the ore worked by pits Nos. 1 and 2, and

leave the original cavern intact?" it was amusing to preceive Mr. Kendall's non-acquaintance with the Gillfoot Park mine, even though "he has had experience of that and every other deposit in the Whitehaven district and Furness." Mr. Kendall says his question is very practical, but the writer must point out that the conditions of mining by man and by nature, so to speak, are very different, and he does not think the members will expect him to enter into the details of mining at Gillfoot Park. The conditions being entirely different, it was quite wrong to make a comparison between the two, man had to make ways—travelling and other ways—which nature had not to do, and he must also point out that water could make its way through cavities, which man could not see with his naked eye. But as before remarked it was not necessary in order to controvert Mr. Kendall's "replacement theory" that the whole of the limestone should have been removed before the iron was deposited, but the two processes of wasting and deposition may have gone on simultaneously in all cases. Besides visiting many or most of the caverns in England Mr. Kendall has been in the United States. Has he visited "the Mammoth Cave of Kentucky?" Is not the area which there stands unsupported at least as great as the Gillfoot Park deposit, and has it not stood so for ages? It was not necessary to make an independent analysis of the thin stratum in the cutting of the mineral railway at Bigrigg, because the mixed nature of the stratum was easily seen, and he had taken specimens from the bed which consisted of hæmatite, mud and sand, or rather "what had once been mud and sand." "The growing together of the limestone and ore is left unnoticed." The writer differs entirely from Mr. Kendall on this point. As already explained he did not think that the limestone and ore had grown together" so much as that the latter had been "growing" while the former was being wasted by the ordinary operation of water. The writer had seen ore of the very best quality entirely surrounded by the cleanest limestone. One case was in the first iron-ore pit which was sunk at Stank-in-Furness just before the large northerly gut of ore was cut. A patch of ore was seen by the writer in the side of the shaft about 12 inches in diameter, and surrounded as above stated. It was surely absurd to ask "if Mr. Shaw's cavernous and sedimentary explanation be correct, why should not these partings be found in all deposits alike?" Neither Mr. Kendall nor the writer have the slightest doubt about the shales which sometimes part the limestone-beds being found in particular parts only, and that hæmatite was found in all parts of the limestone from top to bottom. The latter was an axiom of the profession generally, but these shales being in some cases interbedded, so to speak, with ore were not

at all essential to explain the formation of hæmatite. It was only Mr. Kendall and Mr. Main who look on these shale-beds as "a clenching argument" in favour of the former gentleman's "replacement theory." With regard to the writer's remark that "the different classes of matter (in the ore) became ultimately separated by the affinity of particles" he would answer Mr. Kendall's question by asking him another. How does he account for flints in chalk, otherwise than as the aggregations of particles from mutual attractions among each other as noticed in De la Beche's *Geological Researches*, page 94, when treating of the nodules in the Lias of Lyme Regis consisting of carbonate of lime in clay? On page 97 the same author says:—"Layers of nodules . . . . composed of substances which have separated out from the constituent parts of a mechanical rock after deposition are common in many strata. The ironstone nodules of the Coal-measures seem to have been thus produced." The writer had in his paper applied this principle to the clay and quicksand overlying the ore at the Hodbarrow mines. By the term therefore "affinity of particles" was meant the same thing as by "mechanical attraction of particles" in the part of his paper which referred to these clays and quicksands, the mud and sand in these diluvial drifts having doubtless been thrown down indiscriminately. In the case of the hæmatite deposits there doubtless was a difference in the rate of supply of material, atmospheric changes being sufficient to account for these differences, and for differences in the quality or composition of the ore. Mr. Main's reference to one of the writer's sections applied to Fig. 2, Plate XXXVII. (Gillfoot Park), and not to Fig. 3 (Hodbarrow mines). The writer had not the slightest doubt about the accuracy of Mr. Kendall's sections which were published in connexion with his own papers, and that the beds of shale shown on these existed before the ore was deposited, but he entirely differed from Mr. Main in thinking it impossible that ore should be deposited both below and above such shale-beds by the ordinary operations of water, and he could see no proof of Mr. Kendall's pet "replacement theory" in it.

Mr. Henry White then read his paper on "The Coad Electric Miner's Lamp" as follows:—

THE COAD ELECTRIC MINER'S LAMP.

By HENRY WHITE.

During the last few weeks the writer has several times tried the Coad electric safety-lamps underground, at the Walker colliery, and being highly pleased with the improved light thought that a description of the lamp might be sufficiently interesting to lay before the members of this Institute.

The No. 1 electric lamp gives a light much superior to that of an ordinary safety-lamp, and no doubt would enable work to be done more efficiently underground.

The No. 3 electric lamp should prove very useful for an official, in travelling and examining high places, timber, or loftings; also the rails, joints, lead, gradient, etc., of engine-planes and inclines and working-places generally. It might also be very usefully applied at off-takes, landings, bank-heads, stables, etc.; and at the bottom and top of staples where coals are drawn and safety-lamps are now in use. The writer considers it much superior to the ordinary safety-lamp for use in examining ropes, pulleys, stone, etc., in upcast shafts, staples, etc.

Experimentally it was found that with the ordinary tin-can Davy lamp a piece of white paper 6 inches square could only be seen about 10 yards off, whilst with the No. 3 electric lamp it could be seen at a distance of 40 yards.

This electric lamp reduces the use and generation of electricity down to the level of an ordinary oil lamp, and the light is given at considerably less cost, as one candle-power is given for 10 hours at the cost of one penny.

The battery is a primary single-fluid one, made of ebonite cells, with platinum connexions, which do not corrode in use, the usual fault and trouble with most batteries. No scientific knowledge of electricity is required in its use. To charge the battery the cover is removed, and the cells filled with the fluid; then the zinc plates are dropped in their places when they immediately connect and the cover put on again.

The small incandescent lamp is held on a flexible or yielding support which allows the lamp to be pushed on one side, to prevent it being broken on meeting with a blow; immediately this takes place the circuit of the current is broken, and the lamp goes out; the sparking caused by this

and the making contact takes place in a sealed chamber, into which no gas can enter. When any pressure that pushes the lamp on one side is removed the lamp comes back to its normal position, and is at once automatically relighted. The lamp is further protected by a stout glass envelope or cover.

Fig. 1, Plate X., is a side view of a three-cells miner's lamp. Fig. 2 shows the incandescent lamp pushed on one side with the outer glass envelope broken; in this position the incandescent lamp is extinguished. Fig. 3 shows a four-cell lamp, fitted with a powerful deflecting search-light or lantern, capable of throwing a focussed light of over fifty candle-power to a distance of many yards. This lamp can be detached (Fig. 4) from the battery and held in the hand for searching purposes, to obviate the necessity of turning or of holding the battery in inconvenient positions. Fig. 5 is a sectional view of the battery, showing the insertion of a zinc plate. This plate is supported on the projections A, one side of which rests upon the platinum contact-points B, thereby completing the connexion of the zinc with the carbon.

The weight of the lamp shown in Fig. 1, when fully charged, is 4 lbs. 2 ozs., and that of the lamp shown in Fig. 3, 5 lbs. 6 ozs.

One charge of 10 ounces of the improved bichromate-of-potash fluid will give ten hours' light.

The consumption of zinc is: for the three-cell lamp, $\frac{3}{4}$ ounce per ten hours; and for the four-cell, 1 ounce for the same time.

Mr. G. B. FORSTER asked if there was any apparatus connected with the lamp to indicate the presence of gas?

Mr. COAD (the inventor of the lamp) said there was not; he had not thought there was any necessity for it. Could not a man smell the gas?

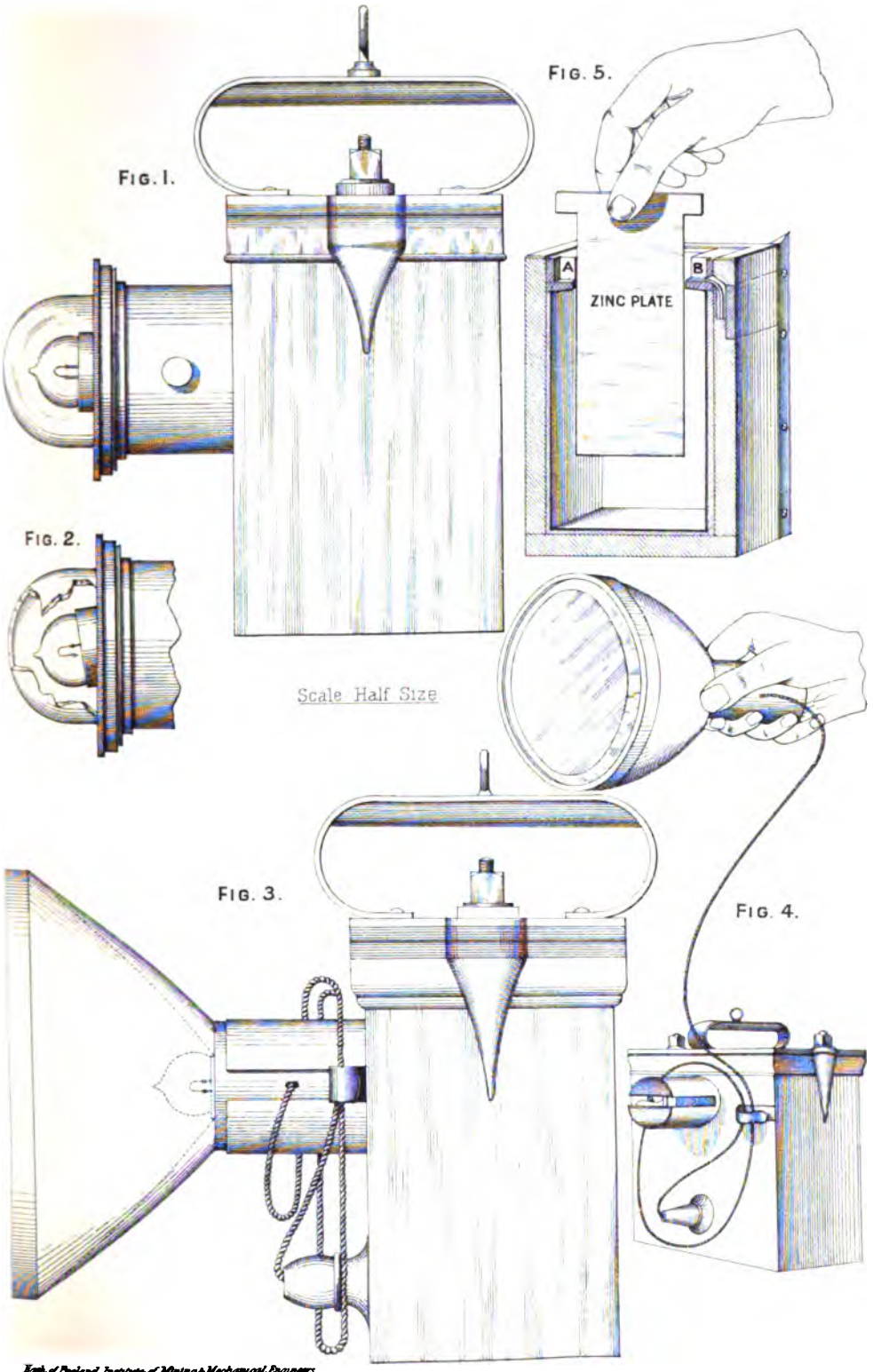
Mr. FORSTER—Perhaps, but not in time to prevent suffocation.

Mr. W. C. BLACKETT asked if the makers of the lamp were prepared to maintain it at the cost named, of 1d. per candle-power per 10 hours?

Mr. COAD said they did not undertake this, it could be a matter for arrangement.

Mr. BLACKETT also asked if the fluid could be bought in the open market?

To illustrate Mr Henry White's Paper on "The Coal Electric Miners' Lamp."



Mr. COAD said that arrangements could be made for colliery owners to make their own.

Mr. BLACKETT—Free of royalty?

Mr. COAD could not say that.

The PRESIDENT proposed a vote of thanks to Mr. White for bringing this electric lamp before their notice; it was very interesting and might be found very useful.

The motion was agreed to.

Mr. WHITE acknowledged the vote of thanks and said he had found the lamp very useful.

Mr. J. H. MERIVALE'S paper on "The Education of Mining Engineers"* and Mr. BRYAN DONKIN'S paper on "Steam Boilers with Forced Blast: the Perret System for Burning Dust and Rejected Fuels; with Notes on Testing Boilers" were taken as read, and the meeting closed.

* This paper will be published as an Appendix to the present volume of the *Transactions*.

STEAM BOILERS WITH FORCED BLAST: THE PERRET SYSTEM FOR BURNING DUST AND REJECTED FUELS; WITH NOTES ON TESTING BOILERS.

By BRYAN DONKIN, Jun., M.I.C.E.

Introduction.

In working modern steam boilers economically, the question is, not so much to burn any large coal obtainable in the market, as to consume, if possible, what cannot be burnt in the ordinary way. In other words, to go direct to the pit's mouth, or other centres, not to purchase good coal, but to find out and endeavour to use the refuse heaps that are often accumulating there, the cost of which, of course, is much less.

Any invention tending to promote the use of small or dust coal, coke, etc., is deserving the attention of steam and heat consumers, especially in colliery districts. Heat should be bought in the cheapest form and utilized in the best way for the production of steam.

A boiler is simply a heat apparatus to evaporate water under pressure by means of some kind of fuel. The object should be to evaporate the maximum weight of water per hour at the minimum cost of fuel. The products of combustion should not be allowed to escape too hot.

The best standard of comparison, as will be seen later on, is the cost of the fuel consumed per 1,000 gallons of water converted into steam. In this way boiler results can be readily compared in the same or different districts. The temperature of the water evaporated should be given, and also the pressure of the steam.

There is now a demand for furnaces to burn economically all kinds of refuse fuels, hard dust coke from coke-ovens, coke dust from gas-works, anthracite, washings of coal-mines, screenings, etc. Many grates are at work that will burn even house refuse from dust-bins, etc.

Use of Forced Blast.

It is impossible to burn those classes of fuels, which are in the form of dust, thoroughly, without more oxygen and more heat. In the ordinary grates the quantity of air admitted to the grate is limited by the

pull of the chimney of say $\frac{1}{4}$, $\frac{1}{2}$, up to $\frac{3}{4}$ inch of water. The maximum vacuum the author has found in a very high chimney is about $\frac{3}{4}$ inch of water.

Hence the necessity for supplying large quantities of air under a small pressure to the furnaces. The easiest way of doing this is by means of a small fan placed near the boiler, forcing the required volume of air into the furnace under a water-pressure of about $\frac{1}{3}$ to $\frac{3}{4}$ inch. Provision must also be made for cooling the bars, to prevent the clinker adhering and the bars from getting hot, so that they may last several years. Of course, if a chimney exists, the vacuum or pull produced can be utilized as well as the air pressure under the bars. If a chimney has to be constructed, one of smaller height and much less cost than usual is sufficient with this system.

To ascertain, if required, whether too much or too little air is introduced, the gases of combustion should be analysed by means of a very simple apparatus.

It should be remembered that forced chimney draught has been used for more than half a century in locomotives, the exhaust steam from the cylinders escaping up the chimney causing a considerable vacuum in the chimney, the tubes, and the fire-box. In some locomotive experiments, made recently by the author, where the water and coals were carefully measured during a run of 100 miles, the vacuum in the chimney with 14 coaches going uphill was found, by the water-gauge, to be about $2\frac{1}{4}$ inches. On the level it was about 1 inch.

In modern marine practice, forced blast and forced draught have not been many years in use, but they are now very generally employed in tubular marine boilers either with or without closed stokeholes. The pressure varies from 1 to 3 inches, and is produced by fans.

In agricultural engines, as in locomotives, a vacuum is produced by the usual blast in the chimney, by means of exhaust steam.

The Perret System applied to Land Boilers.

This system was invented by the celebrated chemist and scientist, Mr. Michel Perret of Paris. His name is well-known in France as the inventor of several very ingenious kinds of furnaces for heating buildings, etc., and his arrangement can be applied practically to all kinds of steam boilers, either new or old.

Figs. 1, 2, 5, and 6, Plate XI., show the Perret grate as applied to the Lancashire boiler. It will be seen that the bars K are much thinner and deeper than is usual in ordinary grates, and present much larger

cooling-surfaces. On an average each bar is about $\frac{5}{8}$ inch thick at the coal-line, $\frac{3}{8}$ inch thick at the water-line, and about 2 feet long. The bars are placed very near together, being only about $\frac{1}{10}$ inch apart, and are 9 inches deep.

Under the grate there is a shallow, cast-iron, open tank or trough D, which is always kept automatically full of water, by means of a ball cock A. Into this tank, as will be seen in the figures, all the bars dip, so that they are immersed from $2\frac{1}{2}$ to 3 inches at their lower extremities. For this reason the Perret furnace is often called a "water-cased grate." The bars are kept much cooler than usual by their being constantly in water. The temperature of the water is generally about 110 degs. Fahr., and the evaporation from each trough about 1 gallon per hour. The vertical currents of air between the bars at atmospheric temperature also tend to cool them, as well as to prevent the dust from falling into the tank; the tank can easily be cleaned out every two or three weeks, through a special door G. One advantage of this system is that the bars are kept cool, and therefore the clinker does not adhere to them, as with ordinary bars. If the burning coals are removed from the bars, the bars can be touched by the fingers without danger. The clinker can, without any effort on the part of the attendant, be lifted and removed. For this reason these cast-iron bars last long and do not lose their shape in four or five years.

The temperature of the furnace is somewhat higher with forced blast than without; there is also better combustion, as the analyses of the chimney gases show, with the production of very little or no carbonic oxide gas. Another advantage is that a small quantity of the water from the open top of the tank, in which the bars are immersed, is continually evaporated. The moisture thus given off has been shown lately by experiments to assist combustion, and to diminish the quantity of clinker, as well as the smoke.

Figs. 5 and 6 show where the air enters by pipes E to each grate. The whole of the lower part of the grate, between the water-line in the trough and the coal-line on the top of the bars, is under pressure.

These furnaces are suitable for, and have been added to, all types of steam boilers, both with internal and external fires, burning all kinds of small and dust fuels. In factories and mills where there are many boilers, one boiler is sometimes fitted with this grate for consuming all the refuse and ashes coming from the other boilers.

The weight of fuel that can be burnt per square foot of grate per hour varies of course much, according to circumstances, but 10 to 20 lbs. is the

usual consumption. As much, however, as 30 to 35 lbs. have been burnt per hour per square foot. More even can be burnt, but this generally means waste of heat.

Figs. 3, 4, 7, 8, 9, and 10, Plate XI., show applications of this system to egg-ended, tubulous, and locomotive type boilers.

The economy obtained in practice by the adoption of the Perret forced-blast grate, as compared with the ordinary system, is generally about 50 per cent. in the annual coal bills, as much cheaper fuels can be burned, but it varies from 30 per cent. to 60 per cent. In London the economy is often 50 per cent., at collieries about 40 to 50 per cent.; it, however, depends, as in other places, upon the price of the dust fuel, as compared with that used previously. In France it almost always halves the coal bills.

With this system, if more steam is required for a short time it can be obtained. Generally boilers with the Perret grates can be made to burn more fuel and evaporate more water than with ordinary grates, but this depends on the quality of fuel. The blast can be regulated to suit the varying quantities of steam required during different times of the working day. With high or low class fuels it is not recommended to force boilers, as this means waste of heat and uneconomical working, unless large economizers are used to reduce the temperature of gases by putting some of this heat into the feed-water.

The bars are practically the only parts of the apparatus subject to wear, and these generally last four or five years.

The boiler flues in all boilers should be large so as to be readily cleaned. The brickwork should be good, and with an air space to diminish radiation. Fronts of steam boilers should always be covered to keep the boiler at as uniform a temperature as possible and to reduce the waste of heat.

On the Measurement of Feed-water to Steam Boilers.

To ascertain really what a boiler is doing, it is essential to know the quantity of water evaporated per hour for a given weight of fuel consumed. This is the only practical method of finding out the work done with a given quantity of combustible burnt or heat given off; this heat is taken up by a known area of heating surface exposed to the flames, and hot gases.

There is a great difficulty in getting mill owners, engineers, and others to measure their feed-water, and yet this is as easily done as measuring gas by meters. In collieries and large factories, with 10, 20, or 30 boilers, there is seldom a meter fixed even to one boiler. There are in England some 100 to 150 boilers provided with meters known to the author. He recommends that one boiler at least should be an experimental

one, to find out evaporative facts, and that it should be provided with means of measuring the feed-water, doing of course its usual work at the same time.

There are now many good serviceable water-meters that will register the feed-water, as it passes into a boiler from a feed-pump, within 2 or 3 per cent. of the actual quantity. The author has had a good deal of experience with different water-meters, and has tested many by means of gauged tanks. They should be lined with brass, and have brass piston rings. The piston type of water-meter is generally the best and most reliable.

A careful daily and weekly record of the weight of fuel burnt and the quantity of water evaporated always conduces to economy, as it enables comparisons to be made of different fuels, stoking, etc. A form recommended for this purpose is added. (See Appendix D.)

When all the water is used for power, the meter of course gives the consumption of the steam to the engine or engines, an important point to determine. At the Bermondsey works such a daily record has been kept for seven or eight years, and at many other factories the same is done.

The author considers that boiler owners and engineers should ask themselves the following questions, and make arrangements to solve all or most of them :—

1. What is the heating value of the fuel burnt ?
2. What is the evaporative power of the boiler used, having a given heating and grate-surface ?
3. What is the value of the economizer or feed-water heater ?
4. What is the rate of evaporation and combustion per square foot of heating and grate-surface ?
5. What is the best method of stoking and best thickness of fires ?
6. What is the temperature of the gases escaping up the chimney and wasted ?
7. What is the cost of the fuel used for the evaporation of 1,000 gallons of water per hour ?
8. What draught is the chimney giving ?

How few can answer these and other questions even approximately !

The number of pounds of steam produced for each pound of fuel should be known, or in other words, how much water is forced into the boiler by the feed-pump, to replace that evaporated into steam. A good plan, and one practised in France, is to give the stoker a pecuniary interest in the saving of fuel or in the evaporative results. Owners will soon recoup themselves for the cost of the meter, etc., by the economy obtained.

In one large mill in Belgium the owner pays the coal merchants, not by the number of tons of coal delivered and burnt, but by the number of

tons of water evaporated or steam made, so that the coal merchants are directly interested in sending him a clean, good, economical coal, with the smallest percentage of incombustible matter. This plan works well and seems an excellent one.

The meter should not be placed on the suction of the feed-pump, but on the delivery pipe between the pump and the boiler, and it should be provided with a bye-pass for the water.

Some thousands of meters are used in France, Germany, and Switzerland, both on sea and on land, for measuring feed-water.

Let us take a given district, say London or Newcastle, and let us suppose that it is desirable to compare the economic results of various fuels, and to have a practical standard of comparison for different boilers, fuels, and stokers, etc. This is the more important, as there are so many different classes of boilers in use, evaporating water with very different priced fuels, with different pressures of steam and different stokers, either mechanical or manual.

The cost of fuel per ton varies in London from 5s. to 24s., or in the proportion of nearly 5 to 1. In addition to this, the evaporation varies from 5 to 10 lbs. of water per lb. of fuel, or in the proportion of 2 to 1.

To compare these results, some standard should be fixed, combining the cost of fuel with its evaporative efficiency, or steam-producing power of the boiler. The best unit of comparison is, in the author's opinion, the cost of fuel for evaporating 1,000 gallons of water per hour at a certain temperature. In this way a boiler burning so many tons of coal, and evaporating so many thousands of gallons of water, can be compared with another boiler having a different evaporative power and supplied with a different fuel.

As steam boilers are required for evaporating water, the question is how to do it at the most economical rate. This can only be done by using a fuel giving the best evaporation at the price, which may be determined by some such method as here described. Three examples are now given to make the matter clearer.

Experiment	Kind of Fuel.	Cost per Ton.	Water Evaporated per lb. of Fuel by Experiment.	Cost of Fuel per 1,000 Gals. Water Evaporated.
			Pounds.	
A	Dust coke on Perret grate	5s.	6	3s. 8d.
B	Dust Welsh coal on Perret grate	10s.	8½	5s. 2d.
C	Ordinary large Welsh coal on ordinary grate ...	22s.	9	10s. 11d.

The above are all actual experimental results at the same steam pressure.

It will be seen that B is less than half the cost of C per 1,000 gallons of water evaporated, and A is considerably less than B.

The cost of using these three very different classes of fuels with the same boiler and the same stoker is thus in the proportion of the numbers 22, 31, and 65. Using dust Welsh coal in lieu of large Welsh coal will be seen to halve the coal bills for the same quantity of steam generated or water evaporated.

On the Belgian State railways, a proportion of all the coal supplied by the contractors is always tested under fixed locomotive boilers, and with the pressure of steam used on the railways. The coal is refused unless it passes the evaporative test of so many lbs. of water per lb. It is also rejected if the percentage of dirt or incombustible matter is above the limits defined. The same chimney blast is used as on the railways.

The author has assisted at one of these official tests, which are very well and carefully carried out by capable experts. He believes the same system is in force for the coal purchased by contract for the German Imperial Navy. In England we are too careless in these matters.

Many of the boiler associations, both in England and on the Continent, are continually doing excellent work in making and publishing accurate boiler tests in which the water, coal, clinker, etc., are all carefully weighed, and various other additional details are given. The gases of combustion are analysed, and their temperature noted, both before and after passing the economizer.

If coal users are buying an ordinary coal, they often pay 1s. to 2s. per ton for useless incombustible matter. The weight of ash and clinker in fuels varies, as a rule, from 3 to 20 per cent., and yet how seldom is the amount determined or thought of. It should certainly be measured now and then, and regularly if possible, as a check. Shrewd business men, if they know it, are not in the habit of paying 1s. to 2s. per ton for useless dirt.

The trials made by Mr. Michael Longridge, of Manchester, are especially valuable, and his interesting annual reports are year by year more complete. Ten years ago nothing so comprehensive was undertaken. He is doing good work in calling attention to the great waste of money in heat and fuel continually going on. The Association Alsacienne des Propriétaires d'Appareils à Vapeur at Mulhouse have also published boiler tests annually, in the same systematic manner, for the past thirty years. To make and work out experiments properly requires a great deal of time, and is

fatiguing, and continuous observations made every 10 or 15 minutes for 12 hours are no light task even to young men. Those who have superintended them know the careful preparation needed to draw out the different working sheets for the detailed observations, giving orders to each of the numerous assistants, checking the instruments, etc. Then there is the actual trial, lasting say from 6 a.m. to 6 p.m. without leaving the hot and dirty boiler-house, etc. After this, the other half of the work has to be done, *i.e.*, the results must be all worked out, checked, tabulated, and the report made.

Experimental Boiler Results with Perret Furnaces.

Appendix A contains an accurate test made by Prof. Kennedy, F.R.S., and the author, on a Lancashire boiler at the Bermondsey works. It will be seen that besides all the details, a heat balance-sheet has been made out, accounting for nearly the whole of the heat given to the boiler.

The expression, "pure and dry coal," is used in these experiments; it means that the weight of clinker, ash, and moisture in the coal has been deducted.

Appendix B records various evaporative results from twenty-eight different kinds of fuels, from a number of experiments at the Bermondsey works on a Lancashire boiler. It will be noticed that the weight of water evaporated per lb. of fuel varies from 2 lbs. to 10 lbs., and the percentage of incombustible matter from 2½ to 36 per cent. This shows the importance of considering the latter factor carefully in all boiler tests.

Appendix C is a summary of results with dust coal from the Moss Hall colliery, made in August, 1892.

The Burning of House-refuse.

As the question of burning ash-bin and other refuse is being much discussed at the present time, it may be well to add a few words on the suitability of Perret furnaces to burn such refuse. In London and many other towns refuse is simply burnt to destroy it on sanitary grounds, but without utilizing at the same time the heat of combustion. It is often desirable to burn refuse, and utilize the heat under steam boilers for the production of steam, etc.

Municipal and town authorities often require power for various purposes which in many cases could be utilized for the production of electric light by means of steam engines

Several of the Perret furnaces are placed under steam boilers burning house refuse. Some are at work in the borough of Warrington, under the direction of Mr. Longdin, the engineer, where the refuse is completely consumed without being screened. The arrangement (Figs. 11 and 12, Plate XII.) is worked in connexion with the Manlove and Alliott destructor, and seems to answer perfectly. Of course, the object in burning refuse should be not only to destroy it, but to utilize the hot gases. At Warrington, the refuse is burnt without producing a nuisance, and the clinker formed is about one-sixth of the total weight. The grates are considerably inclined to assist in getting the refuse into, and the clinker out of, the furnaces. The large quantity of clinker made is utilized in various ways, foundations for paving, etc. The steam is used in connexion with a system of concentrating sewerage, and for driving steam engines.

At Shrewsbury gas works a Perret furnace burns, from time to time, house-refuse. In many cases house-refuse could be burnt with an addition of 10 or 15 per cent. of dust, coal, or coke, and smaller boilers would be sufficient.

Mr. Watson, in a recent interesting paper read before the British Association, mentions several classes of house-refuse destructors. He speaks of ash-bin refuse being burnt under a boiler at Oldham, where he measured accurately the quantity of water evaporated into steam, etc., and found the temperature of the furnace to vary between 1,650 degs. Fahr. and 2,350 degs. Fahr.

APPENDIX A.

Experiments with the Perret Grate, burning Welsh Coal-dust, with Forced Draught, at the Engineering Works of Messrs. Bryan Donkin & Co., Limited, Bermondsey, S.E.

The boiler was of the Lancashire type, 7 feet diameter, 21 feet long, having two internal tubes, 2 feet 9 inches diameter, with three conical water-tubes in each. The fire-grates were each 1 foot 10½ inches wide, and 4 feet long; together equal to 15 square feet. The forced blast was supplied by a small fan.

The fuel used was the dust from the Nixon Navigation (Welsh) coal of the following analysis:—Carbon, 88·58 per cent.; hydrogen, 4·10 per cent.; sulphur, 0·66 per cent.; nitrogen, 1·00 per cent.; oxygen, 2·76 per cent.; and ash, 2·90 per cent. The heating power of the pure and dry coal as determined by a calorimeter was 15,955 thermal units, equal to an evaporation of 16·5 lbs. of water from and at 212 degs. Fahr. per lb. of coal.

The average cost of evaporating 1,000 gallons of water with dust Welsh coal, costing 8s. per ton delivered, is 4s. 5d., including lighting and banking up.

	January 14, 1887.	July 20, 1886
Steam—		
Pressure of steam by a continuous self-recording gauge	50 lbs. per sq. in. ...	57 lbs. per sq. in.
Gases—		
Temperature of issuing gases by mercurial thermometer	399 degs. Fahr. ...	630 degs. Fahr.
Amount of draught in chimney by water-gauge	0·35 in. of water ...	0·40 in. of water
Air—		
Pressure of air below firebars ...	0·10 in. of water ...	0·20 in. of water
Quantity of air theoretically required for perfect combustion of 1 lb. of coal	11·7 lbs. ...	11·7 lbs.
Quantity of air used per unit of coal burnt, or lbs. of air per lb. of coal	25·0 lbs. ...	16·0 lbs.
Lbs. of air used to lbs. theoretically required	2·2 to 1 ...	1·37 to 1
Temperature of air entering grate ...	65·5 degs. Fahr. ...	69 degs. Fahr.
Temperature of air outside boiler-house	34·8 degs. Fahr. ...	64 degs. Fahr.
Temperature of air inside boiler-house	68·5 degs. Fahr. ...	76 degs. Fahr.
Hours—		
Duration of trial: continuous ...	9 hours. ...	12 hours.
Fuel—		
Total fuel used, including ashes, clinkers, and moisture	1,387 lbs. ...	3,332 lbs.
Incombustibles of total fuel (ashes, clinkers, &c.)	7 per cent. ...	3·8 per cent.
Fuel burnt per hour	154 lbs. ...	278 lbs.
Fuel burnt per square foot of fire-grate per hour	10·2 lbs. ...	18·5 lbs.
Fuel burnt per square foot of heating surface per hour	0·29 lb. ...	0·48 lb.
Moisture in coal on day of experiment	5·5 per cent. ...	4·2 per cent.
Gases— Analysis of gases leaving boiler taken continuously, percentages by weight		
CO_2	12·46 per cent. ...	17·35 per cent.
CO	0·00 ,, ...	0·23 ,,
O	10·89 ,, ...	7·16 ,,
N	73·61 ,, ...	70·15 ,,
H_2O	3·04 ,, ...	5·11 ,,
Water—		
Initial temperature of feed-water ...	48·6 degs. Fahr. ...	71 degs. Fahr.
Total quantity of water evaporated during experiments; measured by tank	11,497 lbs. ...	28,427 lbs.
Water evaporated per hour	1,277 ,, ...	2,366 ,,
Water evaporated per hour per square foot of heated surface from temperature of feed-water	2·4 ,, ...	4·06 ,,
Water evaporated per lb. of fuel from initial temperature of feed-water...	8·3 ,, ...	8·52 ,,
Water evaporated per lb. of fuel from and at 212 degs. Fahr.	9·9 ,, ...	10·01 ,,

BALANCE SHEETS OF THERMAL UNITS, PER LB. OF PURE AND DRY WELSH COAL-DUST.

Experiment of January 14, 1887.

HEAT EVOLVED.	Thermal Units.	Per-centages.	HEAT ABSORBED, ETC.	Thermal Units.
Heating power of 1 lb. of coal, pure and dry, as determined by a calorimeter	15,955	68·7	In feed-water evaporated	10,959
		16·4	In issuing gases... ...	2,623
		6·7	Radiation	778
		0·7	Heat in ashes, clinkers, and fuel drawn from grate...	117
		7·5	Unaccounted for ...	1,478
Total	15,955	100·0	Total	15,955

Experiment of July 20, 1888.

HEAT EVOLVED.	Thermal Units.	Per-centages.	HEAT ABSORBED, ETC.	Thermal Units.
Heating power of 1 lb. of coal, pure and dry as determined by a calorimeter	15,955	65·9	In feed-water evaporated	10,530
		23·3	In issuing gases... ...	3,710
		5·1	Radiation	812
		1·2	Lost by incomplete combustion	186
		4·5	Unaccounted for ...	717
Total	15,955	100·0	Total	15,955

It will be seen that these two experiments differ considerably in the rate of fuel burnt per square foot of grate and rate of water evaporated per square foot of heating surface, the same Welsh coal-dust being used in both.

APPENDIX B.

TWENTY-EIGHT EVAPORATIVE RESULTS OBTAINED BY THE PERRET FURNACES WITH VARIOUS FUELS, WITH FEED-WATER AT 80 DEGS. FAHR.

DESCRIPTION OF FUEL.	Lbs. of Water Evaporated per lb. of Fuel.	Percentage of Clinker and Ash.
Best Welsh coal (small), Nixon Navigation ...	9 to 10 ...	2·4
Cheshire coal, Orrel Co.	8·7 ...	2·4
Ordinary Welsh dust	7·9 ...	3·9
" " Murrel's	7·8 ...	7·5
Welsh house slack	6·76 ...	7·5
" smudge	6·5 ...	23·7
Newcastle large coal	7·6 ...	4·5
" Wallsend dust	7·26 ...	5·3
Chesterton Colliery, small	6·97 ...	10·66
Nottingham, small	6·5 ...	12·9
Vron colliery, small	6·4 ...	9·4
Babbington colliery, smudge	6·3 ...	8·6
Leicester, small	5·7 ...	8·6

Description of Fuel.	Lbs. of Water Evaporated per lb. of Fuel.	Percentage of Clinker and Ash.
Welsh, anthracite peas	7·28 ...	5·3
Clay Cross, small	6·5 ...	10·0
Welsh, anthracite dust	6·35 ...	6·2
Irish, anthracite culm	4·37 ...	19·5
Ordinary coke	6·85 ...	11·9
Best coke breeze	6·5 ...	10·0
Ordinary breeze (London)	5·4 ...	19·6
Dust breeze	4·4 ...	32·5
Pan breeze from under retort furnaces	3·32 ...	28·6
Refuse breeze from ironworks	4·5 ...	17·5
Cinders from Tunbridge	2·4 ...	36·0
Pyrites coal-waste from South Wales	3·68 ...	35·5
Cocoanut shells	3·3 ...	—
House-refuse, (not sorted), from Warrington ...	2·13 ...	23·5
" " Chelsea	2·5 ...	35·3

APPENDIX C.

Summary of Experiments made at the Engineering Works of Messrs Bryan Donkin & Co., Limited, Bermondsey, S.E.

The experiments were made on a Lancashire boiler fitted with Perret furnaces the heating surface was 582 square feet; the grate-surface was 24·72 square feet; the average pressure of air under the firebars was ½ inch; the fires were from 5 inches to 9 inches thick; the steam pressure varied from 55 to 59 lbs. per square inch; the mean temperature of the feed-water was 67 degs. Fahr.; the feed-water was measured in a graduated tank; and the fires were clinkered twice during each experiment.

No. of Experiment.	Description of Fuel used, from Moss Hall Colliery.	Duration of Experiment	Appearance of Smoke.	Moisture in Fuel.	Clinker and Ash in Fuel.	Total Fuel used.	Total Water Evaporated.	Gross Evaporation of Water per lb. of Fuel from Temperature of 67 degs. Fahr. of Feed-water.	Gross Evaporation of Water per lb. of Fuel from Temperature of 212 degs. Fahr.
		Hours.		Per Cent.	Per Cent.	Lbs.	Lbs.	Lbs.	
1	Dust coal alone	9½	Very smoky	6¼	12·50	3,136	18,200	5·80	6·80
2	Do.	9½	Do.	6¼	11·32	—	—	5·86	6·90
3	½ dust coal and ⅜ unscreened gas coke breeze	9½	—	—	16·66	—	—	5·30	6·25
4	½ dust coal and ½ unscreened gas coke breeze	9½	—	—	15·17	—	—	5·10	6·00

APPENDIX D.

Steam Boilers.—Daily Return of Fuel and Water, Etc.

No..... Boilers at.....for week ending.....

Date.		Boiler.				Fuel.				Feed-water.					
18 Month.	Date.	Number of Hours under Steam.			Average Pressure of Steam.	Weight of Fuel Burnt. B.	Weight of Clinker and Ashes. A.	Percentage A. of B.		Reading of Water Meter or Tank at o'clock.	Quantity of Water Consumed.	Average Temperature of Water.	No. of Hours Engine Run.		
		From	To	Total Hours	Lbs.	Lbs.	Lbs.	Per Cent.			Lbs.	Degs.	Hours		
Monday ...															
Tuesday ...															
Wednesday ...															
Thursday ...															
Friday ...															
Saturday ...															
Totals ...															

Remarks.—Give date whenever boiler is cleaned or inspected, also when flues are cleaned.

Kind of fuel .....

Temperature of gases, if taken .....

Number of times boiler blown off .....

Damper generally.....open

Lbs. of water evaporated per lb. of fuel (including lighting and banking up) .....

Name of stoker this week ....

Average cost of fuel per ton, delivered into boiler-house .....

Cost of fuel per week ....

Cost of fuel per 1,000 gallons evaporated .....

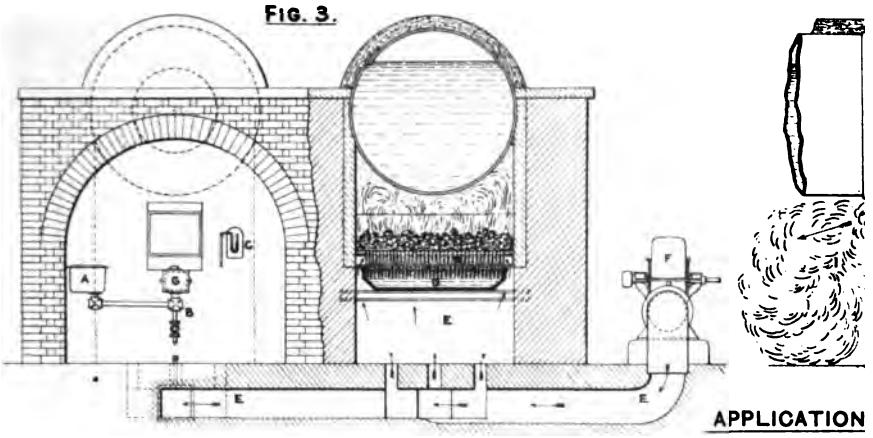
Inches by gauge glass.....ins. = ...lbs.

Signed and checked by.....

Federated Institution of Mining Engineers.
Transactions 1892-93.

To illustrate Mr. Bryan Donkin jun

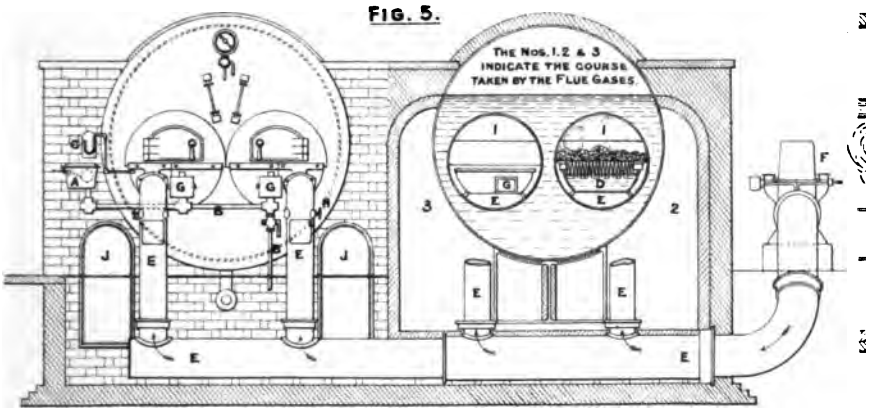
FIG. 3.



FRONT ELEVATION CROSS SECTION

APPLICATION
EGG-ENDED BO

FIG. 5.



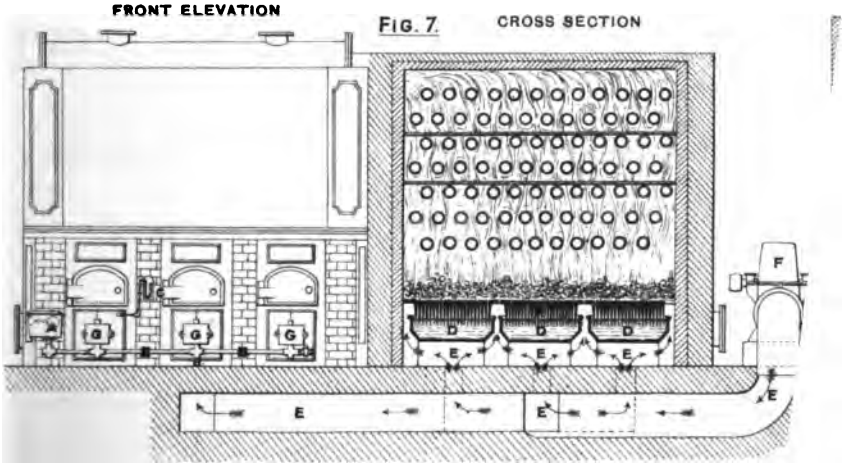
FRONT ELEVATION CROSS SECTION

APPLICATION TO LANCASHIRE B

FRONT ELEVATION

FIG. 7.

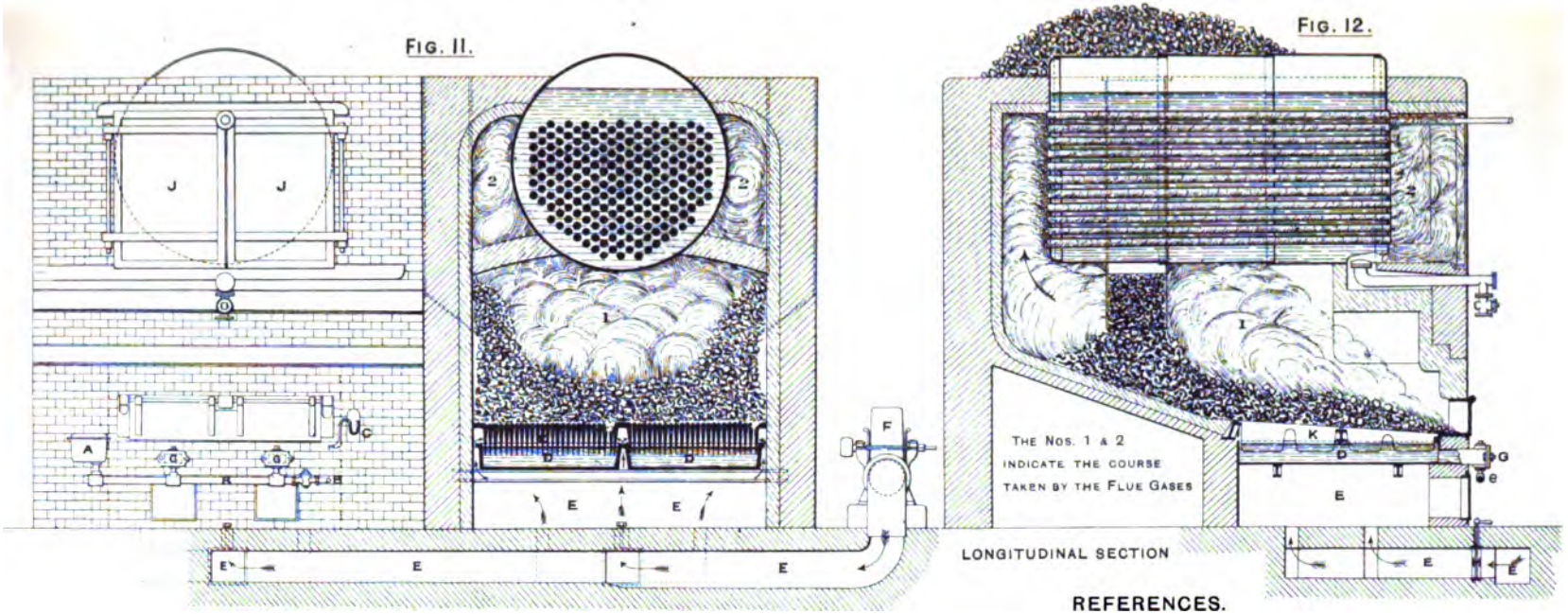
CROSS SECTION



APPLICATION TO TUBULOUS BOIL

North of England Institute of Mining & Mechanical Engineers
Transactions 1892-93.

To illustrate Mr. Bryan Donkin, junrs Paper on "Steam Boilers with forced Blast, &c."



FRONT ELEVATION

CROSS SECTION

APPLICATION FOR BURNING REFUSE IN TUBULAR BOILER

REFERENCES.

A—Water Cistern, with Ball Cock to supply Trough.
B—Drain.
C—Air-pressure Gauge.
D—Water Trough.
E—Air under pressure from ½ in. to 1 in
F—Fan.
G—Door for Cleaning Trough.
H—Air Throttle Valve.
I—Gases under Vacuum produced by Chimney.
J—Flue Door.
K—Fire Bars.

Andw Reid Sons & Co Lithos Newcastle

NOTES ON THE OCCURRENCE OF MANGANESE ORE NEAR THE ARENIGS, MERIONETHSHIRE.

By EDWARD HALSE, A.R.S.M.

Mr. Edward Halse communicated the following addendum to his Notes*:—

The following is a complete analysis, by Messrs. Johnson, Matthey, & Co., of a specimen of manganese ore from the principal vein in the district (Plate LXI., Fig. 4):—

	No. 4. Per Cent.	
Peroxide of manganese	55·3	= 48 metallic manganese.
Protoxide of manganese	12·3	
Oxide of iron	7·2	
Oxide of cobalt	1·4	
Alumina	6·8	
Magnesia	0·4	
Lime and barytes	traces	
Sulphur	0·1	
Phosphoric acid	0·1	= ·043 phosphorus.
Silica and insoluble matter ...	10·0	
Combined water	5·8	
Loss	0·6	
	100·0	

The following are partial analyses of ore from some of the other veins:—

	No. 5. Per Cent.	No. 6. Per Cent.	No. 7. Per Cent.
Metallic manganese	49·13	48·00	38·40
Silica	2·14	9·00	7·92
Phosphorus	0·16	0·38	0·26

The metallic manganese varies from 38 to 54 per cent. (see page 946), the silica and insoluble matter from 2 to 10 per cent., and the phosphorus from ·043 to 1·608 per cent.

* *Trans. Fed. Inst.*, vol. iii., page 940.

Since the notes were written, a paper* by Mr. Charles Vattier was read before the French Society of Civil Engineers. This writer asserts that manganese ores occur in Chili in veins, traversing Jurassic limestone and other rocks, varying in thickness from 3¼ to nearly 10 feet, as well as in seams and irregular masses. The author observes that generally, at a very slight depth, the quality and contents of the ore are lowered appreciably, the gangue becomes more quartzose, red hydrated oxide of iron taking the place of manganese oxide, and in many cases, notwithstanding superficial indications of great richness, the ore diminishes considerably, and even disappears altogether at a depth of 45½ to 48¾ feet.

* "Le Chili; Mineur, Metallurgique, Industriel."—*Mémoires de la Société des Ingénieur Civils*, series 5, vol. xlv., pages 37-140.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE INSTITUTE ROOM, BARNSLEY, OCTOBER 12TH, 1892.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members of the Institute, having been previously nominated:—

MEMBERS—

Mr. RD. BRADLEY, Engineer, Victoria Foundry, Wakefield.
Mr. W. W. CLAYTON, Engineer, Hudswell, Clarke, & Co., Locomotive Builders, Leeds.
Mr. W. DEAN, General Manager, Orrell Collieries, Wigan.
Mr. G. A. MEYER, Mining Engineer, Shamrock Collieries, Westphalia.
Mr. JOS. OXLEY, Mechanical Engineer, Wombwell Main Colliery, Barnsley.
Mr. J. G. PRIESTLEY, General Manager, Glass Houghton Colliery, Castleford.
Mr. H. TATE, Mechanical Engineer, Rylands Main Colliery, Barnsley.
Mr. J. R. WILKINSON, Colliery Enginewright, Mapplewell, Barnsley.
Mr. T. H. WORDSWORTH, Mining Engineer, West Riding Collieries, Normanton

The PRESIDENT gave notice that at the next meeting he would propose that the Professor of Engineering at the Yorkshire College, should be elected an Honorary Member of the Institute. He believed that Prof. Goodman would be a valuable acquisition by reading papers and helping in the discussions.

The PRESIDENT then read his inaugural address as follows:—

PRESIDENTIAL ADDRESS.

By Mr. W. E. GARFORTH.

At the annual meeting I expressed my thanks for the honour you conferred upon me by electing me your President for the ensuing year. Though I am conscious that repetition of thanks adds little to their force, yet before proceeding with my address I wish to again acknowledge your kindness, and to assure you that in response to your confidence I hope, with your co-operation, to discharge the duties connected with the office to your satisfaction.

One of the first of these duties is, I presume, to address you upon some of the various matters connected with mining and engineering. The custom of delivering a presidential address has been so generally followed in this Institute that it may now be looked upon as imperative, if it be true that we are governed as much by custom as we are by law.

In endeavouring to select a subject upon which I might say something new, I have experienced considerable difficulty. Almost every matter associated with mining has been dealt with by the Past-Presidents of this and other scientific societies. I should like, however, to take advantage of this opportunity to make a few remarks for the guidance of the younger members of this Institute, with a view of impressing upon them the necessity of obtaining every information connected with the profession of a mining engineer and colliery manager, which each year becomes of greater importance, owing to the increased depth at which coal has to be worked to keep pace with the demand for fuel.

In considering the difficulties connected with mining in the future, it is apparent that each advance towards improvement renders further advances more difficult. In these times we cannot trust to common-sense and experience alone, much as these excellent qualities have in the past helped engineers to accomplish important works. The discoveries which have been the means of so largely benefiting this and other countries have been, especially in recent years, the result of scientific knowledge combined with practical experience. The education therefore of those

who are to follow should consist of first acquiring the theoretical knowledge which practice cannot give, and afterwards the practice which theory cannot give. A combination of these gives judgment. It must, however, be acknowledged that what has been acquired by practice in the past must be acquired by practice in the future. This remark specially applies to the expenditure of large sums of money which cannot be entrusted to the theorist, or to one who has not had the necessary experience as regards the cost of different kinds of material and labour. In gaining experience the young engineer, like the older man of to-day, will undoubtedly meet with certain failures, but failures when properly considered are the best of preceptors, and often form the true pathway to success. It may encourage him to remember the old saying, that "the cleverest men are not they who never make mistakes, but rather they who never repeat them, and if possible turn a failure into a success." With respect to the latter part of the quotation, I am not aware that any profession in the past has overcome difficulties, and converted apparent obstacles into advantages to a greater extent than that of the mining engineer and colliery official. But to effect this, deep study, originality of thought, and dogged perseverance, assisted by the resources of experience, are essential. Some minds can only act upon precedent, but a clever man requires no example; his convictions alone are his law; he does not understand timidity, but he acts whilst others deliberate, and success usually crowns his efforts. Such being the case, and looking forward to the difficulties which may be expected in working coal as deep as it is proved to exist, and utilizing the forces of nature, it is imperative that every advantage should early be taken of acquiring the highest scientific training.

The term of apprenticeship passes all too quickly. Then comes the responsibility of being obliged to carry on the ordinary routine of work, and devoting a large amount of time to the best interests of the concern with which the manager may be connected, after which there is little time left for the study of the latest scientific improvements. Want of time is a common complaint amongst the older members of the profession, I therefore mention the fact as a reminder to the younger members not to neglect the least opportunity of acquiring those fundamental laws on which science generally is based.

In consequence of a remark which was passed at the annual meeting that "the output of coal in Yorkshire was last year, for the first time, the largest of any district in the United Kingdom," I have prepared from the Parliamentary returns the following statistics which show the

annual outputs of coal from the nine leading districts, from the years 1871 to 1891, at intervals of five years, together with the percentage of increase :—

Name of District.	1871.	1876.	Increase per Cent.	1881.	Increase per Cent.	1886.	Increase per Cent.	1891.	Increase per Cent.	Increase per Cent. comparing 1871 and 1891, 20 Years.
	Tons.	Tons.		Tons.		Tons.		Tons.		
Scotland, East ...	8,823,926	11,667,648	32	14,148,880	21	14,423,618	2	14,763,193	2	67
Newcastle	12,530,000	14,135,104	12	15,830,720	12	16,462,491	4	19,338,455	17	54
Durham	17,946,000	19,520,923	9	21,539,809	10	20,117,322	7*	21,475,056	7	20
Manchester	7,575,800	8,489,374	12	9,454,307	11	9,816,773	4	10,941,329	11	44
Liverpool	8,775,000	11,509,389	31	11,843,685	3	13,419,989	13	15,039,214	12	71
Midlands	9,252,900	12,331,546	33	15,545,667	26	16,760,227	8	21,569,151	29	133
Staffordshire, etc. ...	10,500,000	10,000,000	5*	10,058,670	½	8,690,698	14*	10,153,907	17	3*
South Wales	9,120,000	11,663,447	28	16,008,525	37	17,157,926	7	22,038,098	28	142
YORKSHIRE	12,801,260	15,129,506	18	18,287,141	21	19,389,336	6	22,789,935	17	78

* Decrease.

This statement is not as full as I first intended making it, for fear I should trespass on your patience. It is, however, sufficient to show the respective positions of the leading mining counties, and that Yorkshire has the largest output of coal. The increase during the twenty years being at the rate of 78 per cent. During the same period the quantity of coal raised in the United Kingdom has increased from 117,439,251 tons for 1871 to 185,479,126 tons for 1891, or at the rate of 58 per cent.

It is a matter for congratulation amongst those connected with mining that they have by their skill and knowledge been able to produce an output of coal equal to the demand, and at a price which has enabled the English manufacturer to compete successfully with other countries. It is also a matter for regret that the mineral resources of this country are being exhausted at so rapid a rate. This feeling of regret is further increased when we remember the extravagant use of fuel at many collieries, works, and factories, and the large quantity which is annually exported for the use of other countries.

Looking at the foregoing particulars, and considering the fact that the increase in the output of the United Kingdom has been at the rate of 58 per cent., I am naturally reminded of the Royal Commission which was appointed in the years 1866 to 1871 for the purpose of enquiring into the probable duration of the coal-fields and other matters relating to coal in the United Kingdom. It is also a reminder that many collieries in this and other mining districts of this country, from which large quantities of coal have been obtained in the past, are now exhausted, the shafts closed, and the works abandoned. These concerns, many of which worked the coal at a short distance from the surface, have been replaced by larger collieries working seams at a depth which at one time was thought impracticable.

As regards this increased depth, unfortunately there is no return to show the depths at which the coal given in the foregoing table has been worked, consequently it is impossible to state the rate at which the average depth is increasing. The depth of the shaft is no criterion, as seams lying at different depths may, by means of inclines and tunnels, be raised to the same level. It is to be hoped that some arrangement will shortly be made in the Government returns to obtain this information. With a return of the area and thickness of the seams worked, it is possible that an approximate depth might be given, and for obvious reasons this information would not only be interesting to those immediately connected with mines, but important to the consumers, and to those who consider certain questions of this kind from a national point of view.

To give some idea of the rate of increase of depth it may be mentioned that whilst the deepest shaft in 1871 was 2,376 feet, coal is now being worked at Ashton Moss colliery, in Lancashire, at a depth of 3,150 feet vertical, and at the Lambert coal-mine, in Belgium, at 3,490 feet.

The knowledge of the foregoing and other facts suggests the idea that the subject of deep mining is one which might be considered with advantage by the members of this Institute.

Since 1871, great improvements have been made, and much has been done to bring scientific research into practical shape, and to substitute certainty for uncertainty. The improvements in machinery, ropes, and other colliery appliances, especially electrical work, have produced the feeling that coal may be worked at a much greater depth than was deemed feasible a few years ago. Yet we cannot disguise the fact that the great obstacles to deep mining relate to natural laws, the chief amongst which are, increased temperature due to depth, and increased weight due to superincumbent strata.

As against these natural obstacles we must not, at the same time, forget that the coal which has hitherto been discovered at great depths may be considered as valuable as seams lying near the surface; indeed, in some instances, it is of superior quality. The increased thickness and impervious nature of the strata prevents water percolating into the mine. The quantity of gas given off from the coal is no greater in deep than in some shallow seams, etc. We should also consider that the doubts and difficulties expressed by the last generation of colliery officials as to working coal at a depth of 400 to 500 yards, which at one time seemed insurmountable, have since been overcome.

With respect to the increase of temperature, the latest information shows that at Ashton Moss it only increases at the rate of 1 deg. for every 76 feet, whilst the rate of increase assumed by the Commission, based upon the actual facts obtainable at that time, was 1 deg. for every 60 feet. The large quantities of water which have been met with at a certain depth from the surface in the neighbourhood of Ashton Moss colliery may have some effect in reducing the temperature.

It has been hoped that future deep sinkings might prove the increase of temperature to be in a diminishing ratio, but when the primary cause which has led to the increase is considered it is hardly reasonable to expect that such will be the case. High temperature of the strata operates as an impediment to deep working by heating the air circulating through the passages of the mine. This heating process is most rapid at first, when the difference of temperature between the air and the rocks is

greatest, gradually diminishing as the length of the passage is extended, and never ceasing until complete assimilation is effected. As the air in circulation is gradually increased, so the temperature of the strata is reduced by the absorption of heat from them. From experiments conducted by medical men and scientists it has been shown that 180 degs. Fahr. has been withstood in stokeholes of steamers and in glass-houses, 125 degs. in foreign climates, and 90 degs. in cotton mills and other factories.

It has also been proved that the human skin is better adapted to and can withstand a greater heat than that of certain animals. This is due to increased respiration, circulation, and evaporation, by which the body is prevented from being heated above the natural temperature. If a man's body could not lose by evaporation, etc., the heat which may be produced within him, it would intensify and result in death. The depth stated by the Commission at which the temperature would amount to 98 degs., or blood heat, was about 3,000 feet.

As regards the difficulties of maintaining the roadways consequent on the increased depth of the strata, experience has shown that no system of working can reduce the weight of the strata, and this is apparent when we consider that every foot of coal supports a corresponding foot of superincumbent strata, so that if a portion of coal is extracted a weight over and above that naturally intended is thrown on the remaining pillars. This difficulty was not seriously felt in mines lying within 100 to 200 yards from the surface, but as the depth increases the weight naturally becomes greater.

With respect to the foregoing and other natural difficulties, the conclusion arrived at by the Commission was to the effect, that the "increase of temperature and depth was so speculative that they felt it better to leave the question in uncertainty; but looking to possible expedients which the future may elicit for further reducing the temperature, they considered that it might fairly be assumed that the depth of at least 4,000 feet might be reached."

Such being the opinion expressed twenty years ago, it seems to me a fitting opportunity for the members of this and other Institutes to consider what improvements have been made in the interval. If afterwards different methods of overcoming the difficulties I have mentioned are discussed, it is possible the suggestions thrown out may help us to overcome them when they arise. There may be certain natural laws yet to be discovered. It is well to remember that nature does not volunteer information which man may discover for himself, probably for the reason that when man is capable of appreciating it he is capable of discovering it.

I think there is reason to congratulate ourselves upon the great improvements which have been made in electricity during the period mentioned. It has been said that the most sanguine electrician did not anticipate ten years ago the great improvements which have since been made. The conveyance of coal underground is practically the same in a deep as in a shallow mine, and there are other matters which encourage us in the attempt to overcome or minimize the difficulties connected with deep mining.

Considering the deep shafts now being sunk in this and other districts I venture to think it might prove a help to those who are at present engaged in such work to have a discussion amongst the members of this Institute as to the advantages or disadvantages of placing the shafts at some distance apart, with a view of reducing the friction of the air and preventing an increase in the temperature of the mine. The practicability of using small ventilating machines to promote an increased circulation of the air (somewhat in the same way as the punkah is used in India and other hot countries) without interfering with the general ventilation of the mine; also the feasibility of having troughs of water at the sides of the roadways, the extended use of coal-cutting machines, and other appliances. A further description of these points would, however, exceed the limits of this address, but I hope some of the matters I have mentioned may be taken up and lead to a discussion.

Besides obtaining a supply of coal from the deep mines, as already referred to, many seams which until recently have been considered only second-rate, will, no doubt, be worked in the near future. Some of the inducements to do so will be the good reputation and long-established connexion enjoyed by some firms; the exceptional geographical position as regards railway and canal accommodation; the utilization of brick and stone erections, and of many miles of railway sidings, which if dismantled would result in a great sacrifice on the part of the mine owner. With such advantages, and a capital reduced to a comparatively small sum, it is possible some collieries working a seam of coal interstratified with dirt partings may be profitably carried on, especially when in competition with the high price charged for deep coal consequent on the increased cost of production.

Many of the collieries in this country have hitherto had the natural advantage of working rich and thick seams of coal comparatively free from dirt. In consequence of this and the improvements made in screening and picking-tables the public have now been educated to expect clean coal, so that coal containing dirt is not acceptable. It will therefore be

necessary to adopt measures to separate the coal of the seams referred to as second-rate seams from all impurities in a similar manner to that practised on the Continent.

In certain districts which I have visited in France and Germany some seams contain not only dirt partings but a certain proportion of dirt interstratified with the coal. The efforts which were made many years ago on the Continent to separate these impurities proved a serious difficulty until the method of washing the coal on a large scale was adopted. During the past twenty, but especially during the last fifteen years, washing-plants have been so perfected in Westphalia that 600 to 800 tons per day can be washed in sizes varying from 3 to 4 inches cube down to the finest dirt, and at a cost of ½d. to ¾d. per ton for labour.

I intended laying before you several tables of statistics showing the important advantages to be derived by a certain improved system of washing, but I find such particulars would exceed the limits of this address. I am therefore compelled, for fear of trespassing on your indulgence, to postpone such information until a future meeting.

In addition to washing the small coal, the large pieces with a thin layer of dirt adhering are broken up by means of a disintegrator, so that all the coal is recovered and made marketable either as nuts or very small coal, suitable for coke-making. With respect to this latter improvement it is probable that a large amount of the waste which has hitherto taken place in this country will be saved.

If the expectations be realized of those people who believe coal can be worked as deep as it is proved to exist, and if seams of coal with dirt partings can be profitably worked, then I think no fear need be entertained that the supply of coal in the United Kingdom will be exhausted in the period mentioned by Mr. Price Williams in the paper read in 1889 before the Statistical Society. But if such be the case, and the supply of coal continue for a time beyond which we can form no conception, there is no reason why economy should not be practised to a greater extent in the future than in the past. There has been a slight saving in domestic consumption by a better type of fire-grate, and the application of heated air to certain houses and public buildings. There has also been considerable advance in this direction by certain manufactories, especially in the engines and boilers used in connexion with mills and factories, by using high-pressure steam and taking advantage of increased pressure without a corresponding increase of temperature; but notwithstanding these improvements there is still a great margin

for further reducing the consumption of fuel. This remark specially applies to collieries, the reasons for which are too well known to here need recapitulation.

To give a sketch, however slight, of the improvements which have been made in various appliances during the last year, or to mention the interesting papers which have been brought before this and other institutes would, even if I were competent, exceed the limits of this address, but I recommend the papers to your earnest perusal and criticism. I believe the facts which have been described by the writers with respect to the advantages gained will prove of value to other members having similar requirements.

It is hoped the various matters referred to in the preceding remarks, together with the following, will form subjects for various papers to be read during the ensuing session:—Different methods of working coal, including the more extended use of coal-cutting machines; the systems of ventilation, dealing with increased temperature; the more economical use of compressed air; the applications of electricity; the best means of conveying coal underground; the different systems of washing small coal; the use of explosives in those mines where longwall cannot properly be worked; coal-dust; safety-lamps; means for detecting fire-damp; and other matters.

In conclusion, I beg again to remind you that Yorkshire now holds for the first time the leading position in having the greatest output of coal in any district of the United Kingdom. As representatives of Yorkshire, I therefore think the members of this Institute should follow the example which has for many years been so worthily shown by the North of England Institute of Mining Engineers in producing most valuable papers not only for the mining engineer and colliery manager of the North but for the mining-world generally. If some of the gentlemen I have the honour to address will contribute papers giving the result of their scientific and practical experience, I think it will assist in preventing those dreadful accidents we all so much deplore, lessen the difficulties connected with deep mining, and help to increase the greatness and prosperity of the British Empire.

Mr. T. W. Embleton proposed a vote of thanks to the President for his valuable and instructive address.

Mr. J. GERRARD had the greatest possible pleasure in seconding the proposition. It had been a treat to all of them to hear the valuable principles Mr. Garforth had so ably put before them; they must have been the result of very great thought and careful consideration. He was very pleased he had not missed hearing him deliver the address, because it was one thing to hear it and another thing to read it. There were many points which when heard were impressed upon their minds, and determined them to read it over carefully, which perhaps would escape them on a mere reading.

The PRESIDENT returned thanks for the cordial vote of approbation. He then stated it had been intended that two papers should be read before that meeting, but one gentleman was away and another busily engaged. Mr. Teale would however exhibit a new safety-lamp.

DISCUSSION ON "THE PISTON SAFETY-LAMP."

Mr. TEALE then exhibited specimens of a new safety-lamp, and explained its various details, mode of construction, advantages, etc.

The PRESIDENT asked how the gauze was cleaned?

Mr. TEALE said they could easily clean the gauze, but if all the interstices of the gauze, with the exception of those opposite the ventilating holes, were filled up it would be an advantage, because no dirt could get in. It was easily cleaned from the outside.

Mr. JOHN GERRARD remarked that in point of fact it was only necessary to clean the gauze opposite the holes.

Mr. TEALE—Yes, there is no benefit from the other passages.

Mr. GERRARD asked if it was intended to have a bath of carbonic acid gas outside next the gauze?

Mr. TEALE said he had made some experiments several years ago, which resulted in the present arrangement producing the effect suggested.

Mr. GERRARD supposed it was on the principle that the heated air of the top fell down and became a guard of carbonic acid gas through which fire-damp would have to pass.

Mr. TEALE—There are always the products of combustion between.

The PRESIDENT said that the moment the lamp began to burn it began to form carbonic acid gas, and he understood there was always that product between the flame and the outside.

Mr. GERRARD enquired the use of the cone?

Mr. TEALE said the air passed in underneath the cone, while the products of combustion passed off through the top, and the cone was in fact a separator.

Mr. GERRARD said it was one of the most important principles of the lamp.

Mr. TEALE said it was an important principle. He did not say it affected the safety, but it added to the steadiness of the flame. By more complete combustion and steadying the flame they had a smaller deposit of soot on the gauze. He had burnt the lamp with "miners' oil" for twelve hours, and found no soot on the gauze. He had burnt the spirit lamp for twelve hours, and had not a morsel of soot on the gauze in three trials.

The PRESIDENT asked what was the illuminating power? Did the higher part of the lamp act as the Mueseler chimney by giving increased circulation of air?

Mr. GERRARD said the Mueseler chimney with the gauze would be a safer lamp than this without the shield.

Mr. TEALE said the Mueseler chimney with the shield would be a safer lamp than this without the shield, because the real principle of the Mueseler action was that of contracting the outlet—the consumption of gas would produce carbonic acid gas more rapidly than it could get out, and it was thrown down and extinguished the flame. His lamp acted in the same way, but more effectively than the Mueseler lamp. The illuminating power had not been tested by any instrument, only by comparison.

Mr. GERRARD asked if the lamp had been used in a mine?

Mr. TEALE said it had only been brought out during the last three weeks. What had been done was to invite criticism, and to make arrangements that every lamp should be turned out accurately.

Mr. GERRARD remarked it had been said that the whole weight depended on a lead rivet, now some lead rivets were very slight and soft. Could that be obviated?

Mr. TEALE said the first idea was to have a bayonet joint which would have weakened the flange. After hearing all the criticisms, he had come to the conclusion that the best form of rivet had been adopted, and he had designed a small apparatus for securing the rivets.

Mr. JOHN NEVIN asked what was the weight of the lamp?

Mr. TEALE said it weighed 2 ounces lighter than the Marsaut.

Mr. NEVIN—Have you tested the lamp in currents of high velocity?

Mr. TEALE—No.

Prof. ARNOLD LUPTON said he had great pleasure in proposing a vote of thanks to Mr. Teale for his courtesy in introducing the new lamp to their notice. He did so with the greater pleasure because it was not the first time that Mr. Teale had done this for the Institute. Mr. Teale was a man of great experience, and whatever he brought before them deserved their best consideration.

Mr. BURTON seconded the motion, which was carried unanimously.

Mr. TEALE, in reply, said that he had always pleasure in bringing anything forward to interest the members of this or any other Institute.

THE MEETING ROOM.

The PRESIDENT said the Council wished to intimate that they were making preparations so that the meeting room could be utilized more than it had hitherto been. It had been suggested that on certain days—which the Secretary would intimate to them after he had made arrangements—the room should be open, a fire kept during the winter months, and a caretaker provided, so that any member arriving in Barnsley with time to spare before the meetings might come to the room and utilize some of their valuable books. It was hoped that members, especially those resident in Barnsley and district, would take advantage of this change. The question of meeting-days had also been discussed. It had been thought that in meeting always on market days some members had been pre-occupied, they had been present in body but absent in mind. With a view to obviate that it had been suggested they should always meet on Saturdays in Leeds, Wakefield, Sheffield, or Barnsley. The Council were unanimous in this matter, but he should like to hear the opinions of members. They did not infringe any rule by the suggested alteration, some steps should be taken to obtain a better attendance of members. They had 197 members, and it looked strange they could only get an average attendance of about 15. The attendance could not possibly be made worse by altering the day.

Mr. NEVIN said personally he should prefer the meetings not being held on Saturday, but the Council thought that by having the meetings on that day they might attract viewers and people from the neighbourhood of the meeting-place, who could not conveniently attend on other days.

Mr. GERRARD said that by having the meetings on market days they got members who perhaps would not come on purpose to attend an Institute meeting, but there could be no harm in trying the experiment.

Mr. J. MITCHELL pointed out that the room had for years been open for members, but only one gentleman had made much use of it, though there were many valuable works in the library. As to the day of meeting they must select the day which was most convenient to members.

A vote of thanks to the President for his services in the chair was passed, and the meeting closed.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, OCTOBER 17TH, 1892.

MR. WM. HEATH, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

ORDINARY MEMBERS—

Mr. WILLIAM HUGHES, Under Manager, Springwood, Chesterton.
Mr. JOHN LEE, Mechanical Engineer, Whitfield Colliery, Norton-in-the-Moors.

STUDENTS—

Mr. JOHN GREGORY, Student, Sneyd Colliery, Burslem.
Mr. HARRY MITCHESON, Articled Pupil, Dresden, Longton.
Mr. JOHN GOW SWORD, Mining Student, Eastwood House, Hanley.

Mr. JAMES TONGE read the following paper on "Waste of Coal" :—

WASTE OF COAL.

By JAMES TONGE.

The "waste of coal" is a "burning question." The title of my remarks assumes that there is a waste, without at all discussing the question. All who have considered the subject will have watched the dense volumes of unconsumed carbon darkening the atmosphere of all manufacturing towns; whilst others who have had further opportunities of studying the subject will know that far greater waste of coal takes place under the surface than that seen above.

The waste in consumption arising from incomplete combustion is nothing in comparison with the waste from non-combustion, or from coal being left in the mine.

As to waste in working, there are:—

(*a*) Pillars left and afterwards crushed. This occurs mostly in the pillar-and-stall system.

(*b*) Small properties where terms of purchase cannot be arranged are passed by—for the time, as is supposed—but the coal is eventually lost.

(*c*) In some neighbourhoods there are numerous small properties with very crooked boundaries, and barriers of considerable extent are left, where, by arrangement, a much shorter barrier would have answered all purposes.

(*d*) Large barriers are sometimes left as security because plans of old workings cannot be found. It is true that we have now guarded against this to some extent, but not entirely.

(*e*) Coal is left ungotten because of contention amongst owners as to pumping expenses. In the county of Stafford, they have to a certain extent solved this difficulty by the united efforts of many parties, and the results must have been a great national gain.

(*f*) Then there is the very serious loss due to coal being left below when not workable at a profit. The leases of mines are in many cases drawn up in such a form as to lead to the abandonment of large areas, simply because the coal is of less value or is inferior in quality to that

from other parts of the same mine. That is especially the case where the coal is soft and produces much slack; large quantities of it are left below; this is at the same time a loss and a danger.

(*g*) Then there is the great inducement to proprietors to select for working only the best seams and such as present the greatest probability of profit being realized. The owners seldom or never join in exploring or proving their own property; they draw all, pay nothing, and have absolutely no risk.

The colliery worker risks his capital, he bears the expense of proving, he is bound to work so much per year or pay for that which he has not got, and if he fails to pay in any one year, or even in some cases less than a year, he is liable to have the whole of his working-plant taken from him. The writer does not say that it is often done, but the leases give liberty for its being done; and he has a very glaring case in his mind, where it was done under circumstances most dishonourable to the owner of the coal. The writer attributes much of the loss of coal to this particular point; and he must confess that he does not like to see the colliery proprietor risking his money and the miner his life under circumstances so much against them, and which might, and, as he thinks, ought to be altered for the better.

If the members consider the possible or probable duration of the coal-supply they will, the writer thinks, find another great incentive to try to make the most of our conditions at the earliest possible moment.

The writer assumes that all agree that our present and future coal resources are confined to the great Carboniferous system. This contains a definite quantity of coal, variously estimated at from 100,000,000,000 to 200,000,000,000 tons. We need not quarrel about a few thousand millions; the great point is that these resources are slowly, it may be thought, but surely lessening, a source of supply which can never by any means be renewed or replaced. It may be said that the present output is only 200,000,000 tons a year, and that it can never reach more than 400,000,000 tons; at this rate there will be a supply for the next 250 years if the lowest available quantity be taken, or for 500 years if the highest be taken. Or if the highest available quantity and the present output be taken the time will be extended to 1,000 years. But all the same, the end is slowly but surely coming.

But long before the end comes there will be a very definite crisis, a time when the best and uppermost seams will have come near exhaustion; when conditions of temperature and pressure in the lower seams will render mining much more difficult, and when the cost of production will rapidly increase.

Mr. Forster Brown, in a paper read at the British Association Meeting at Cardiff last year, gave the year 1940 as the period when the decline would begin, when the cost of everything dependent upon coal—railways, shipping, manufactures, warming of homes, and lighting of streets—would begin to be burdensome.

Now, the writer thinks that all will agree that waste of any article of either intrinsic or relative value is reprehensible. Much more is it to be condemned when that article is both intrinsically and relatively of high value. A useful and even necessary article that can never be replaced must be intrinsically valuable. Such an article is coal. In what direction, then, may a remedy be sought, or some relief found?

The writer ventures to offer one or two suggestions. He thinks that all will agree that education and technical instruction in all mining subjects, and subjects more or less intimately allied to mining, will be one means of relief. If a large proportion of miners could be educated to do their work in the most effective manner, to get their coal in the best possible conditions in the working-places they have to deal with, and to watch carefully for their own and their fellow-workers' safety; if firemen, under-managers, and managers could and would so far study the "principles of mining" that the coal might be sent out in the best condition, at least cost, in greatest quantity per man, with least loss of life or property; when such conditions were reached the "waste of coal" would be less than at present.

Another help towards reducing the waste would be realized if Government would offer some special inducement to inventors, engineers, etc., for inventions or improvements in colliery appliances, as, for instance, in lamps, explosives, substitutes for explosives, coal-cutters and motors for the same, or for improvements in hauling, winding, ventilating, or draining machinery.

Of course, it would be necessary to accept and even invite the co-operation, or (it may be called) the interference of Parliament in matters relating to mining, where the writer would not seek their aid in other industries.

Finally, the writer leans somewhat to the idea of the nation owning and working the mines; and here he would like to leave the question to the consideration of this Institute.

The writer would gladly see Parliament dealing with leases of mines so as to secure more equitable terms, but he must confess that after much consideration he has failed to discover any plan by which Parliament might, with hope of success, attempt to regulate bargains between owners

and intending purchasers, or between lessors and lessees. He does see the possibility of the nation becoming the purchaser and the worker; the advantages and disadvantages attending the acquisition he will not, however, now enter into. He would welcome any feasible plan that offered a reasonable prospect of saving coal.

Mr. GEORGE CLARK observed that the paper opened a wide field for discussion with regard to lessors and lessees of mines, and he moved a vote of thanks to Mr. Tonge.

The SECRETARY seconded the proposition, and it was carried.

DISCUSSION ON "THE PISTON SAFETY-LAMP."

Mr. W. E. TEALE exhibited specimens of a new safety-lamp, and explained its mode of construction*, advantages, etc., as compared with other lamps.

The PRESIDENT considered that the Piston lamp had the appearance of being a good one.

Mr. E. B. WAIN observed that the Piston lamp marked a decided advance. There had in times past been a good deal of labour occasioned and time wasted in screwing and unscrewing lamps, which had not been examined and cleaned as well as they ought to be on account of the

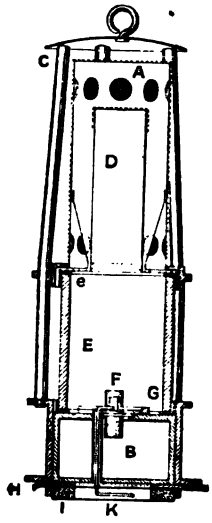


Fig. 1.

* The construction of the Piston lamp is shown in Fig. 1. It consists of five principal parts: a strong case C, into which the various parts are piston-like pushed upwards; comprising an outer gauze and shield A; and the inner tube and separator D; followed by the glass E, with brass rings *e* attached, so that defective or chipped glasses, or those whose ends are not parallel may be used with safety. The oil reservoir B is placed below all the parts, which are kept in the lamp case C by means of the lamp-bottom plate H and a lead-rivet. The wick-tube F is of the ordinary pattern, save that it is maintained in position by means of a slide G instead of a screwed-ring. The lamp-pricker K is of the ordinary pattern. The lamp-bottom plate H is fitted with an elastic cushion I, so as to save the lamp from shock when set down. The wire-gauze is placed outside the shield A, enabling an examination of it to be made at any time.—*Note by Editor.*

difficulties which he thought Mr. Teale had solved. He considered the ingenious way in which Mr. Teale separated the intake and the return air must commend itself to all. Except in the Evan-Thomas and one of the paraffin lamps this principle had not been satisfactorily applied before. The Protector lamp was open to the objection that the explosive gas, given off by the spirit which was burnt in the lamp, was liable to come in contact with the flame, and so cause an explosion inside the lamp. The Piston lamp which burnt spirit was a great improvement on the Protector lamp, as there was a distinct separation between the spirit vessel and the flame.

Mr. W. N. Atkinson (H.M. Inspector of Mines) asked if this lamp had been tested to prove its safety? Another point he wished to call attention to was the locking. Mr. Teale referred to the screw lock. He (Mr. Atkinson) thought the screw lock should be abolished. He hoped Mr. Teale would never make a lamp of which the screw lock formed a part.

Mr. Wain said he had recently had the subject of locking lamps brought prominently under his notice, and was having all screw locks altered to lead locks, which could be done at a cost of 6d. per lamp.

Mr. W. Bridgett said he should like to know whether the Piston lamp had been tested for safety? Would the lamp burn in a strong mixture of gas and air? It was very evident that the lamp which burnt the least quantity of gas mixed with air before it became extinguished was the safest lamp for use where gas was present.

Mr. Atkinson observed that the lamp was not constructed to burn in a mixture of gas and air.

Mr. Bridgett said circumstances occurred at times when it was very necessary for a lamp to be able to burn in a slight mixture of air and gas.

Mr. J. Richard Haines (Secretary) said he was pleased to endorse to a great extent what Mr. Wain had said with respect to the Piston lamp. It was an easier matter to improve than to invent something entirely new, and he thought Mr. Teale had made repeated strides in the improvement of lamps. He did not exactly see how the inner case would not affect the cleaning of the gauze. It did not appear to be easily removed. He supposed it was movable, but if the gauze was to be cleaned properly that tin case must be taken out. He agreed with Mr. Atkinson that screw locks should cease to be used, and he also agreed with Mr. Teale in what he said as to cracked glasses. No doubt lamps were screwed too tightly, and if they got a perfectly parallel joint like this lamp it would decrease the number of broken glasses.

Mr. Joel Settle enquired whether the tin shield inside the lamp increased the temperature?

Mr. R. H. WYNNE asked whether Mr. Teale intended the inner inverted cone to fit close to the shield, so as to make it separate the ingoing and outgoing currents?

Mr. ATKINSON thought the safety would greatly depend upon the inside shield.

Mr. WAIN considered that the safety of the lamp depended upon the rivet at the bottom. If the rivet by rough usage was removed the bottom would drop off, and the lamp fall to pieces.

Mr. TEALE said the india-rubber ring at the bottom of the lamp was applied so as to offer a cushion against rough usage when the lamp was put down. It would preserve the lamp-bottom from being burred, and would not interfere with the cylindrical arrangements of the lamp. The lamp had not been tested, but it had been sent to Mr. C. E. Rhodes, who had kindly consented to do so. He had no doubt when he received Mr. Rhodes' report that it would endorse what he said. When gas fired in the lamp it was confined to the inner tube and checked by the top gauze. When there was an excess of gas the products of combustion would put out the light. At the same time it was not quite so easily put out as the Mueseler lamp. The shield inside the lamp was intended to prevent a direct current passing through the lamp, and it kept the lamp cooler than any other lamp. When the products of combustion travelled up the centre of the lamp, any portion that could not escape fell over the top of the chimney and settled between the cone and that tube. After the lamp had been standing fourteen hours there was no difficulty in holding it by the top without burning the hand. Without the cap on the cone, the flame would fire gas in the top portions of the lamp, and it burnt there in much the same way as in an ordinary lamp, but with the cap at the top of the cone it could never attain that position. He endorsed what Mr. Atkinson said as to the rivet and the screw locks, and he wished he could carry out that view to the fullest extent. The "screw lock" was really a misnomer, but lamp-makers were the creatures of circumstances, and were obliged to carry out arrangements with regard to locking in accordance with the intelligence of those who required the lamps. He had not the slightest doubt that when this lamp was locked, the lead-pin arrangement for locking the lamp was such that it would be difficult to force that lock out. The weight of the Piston lamp was less than that of the best type of Mueseler. In constructing the lamp one thing he wanted to do was to make a strong one. Of course, if they got a heavy fall of roof, the Piston lamp would fail as every other lamp did. He should like to mention an important point in regard to the lamp, and that was that each part was

independent of the other. One little matter which had to be attended to was to see that the glasses were accurate as far as the sizes were concerned, and still more so by having an independent set of rings. They could be put under a small testing-machine so as to get them absolutely parallel, and when that was so the glass went in and the intervening space was filled, and it was impossible for the lamp to get in an incorrect position. In some lamps, though screwed up tight, there was an intervening space sufficient to leave a passage for flame.

The PRESIDENT said the Piston lamp appeared to be a great stride in advance of anything that had hitherto been brought before them.

Mr. RIGBY enquired whether all the movable parts were quite interchangeable?

Mr. TEALE replied in the affirmative. With regard to withdrawing the shield, the portion between the top and the bottom inlet- and outlet-holes was not required, and it was a matter of indifference whether it got filled with dirt. The shields could be taken out by making them looser, or they could be allowed to remain. His own feeling was to have some kind of enamel to close in the whole of the gauze portion, except the top and ventilating holes. There would be a reduction in loss of glass by a large percentage, and the facility with which a man would be able to put the lamps together and clean them ought to do away with a great blot on lamp arrangements; that was, the night work. It could be cleaned by a simple duster. He would have a separate set of lamp-bottoms and a separate set of glasses, to the advantage of efficiency and economy. The lamps coming up to-day, the main portion only required wiping; let them fill the lamp-bottoms, and clean the glass during that day for the next day's work.

Mr. RIGBY intimated that that would necessitate duplicates of portions of the lamp.

Mr. TEALE replied that it would necessitate duplicates of the rings and the lamp reservoir. The cost of the rings would not be above 4d. or 6d. per lamp. The glass would be provided so as to replace broken glasses under any circumstances.

Mr. ATKINSON remarked that there appeared to be sufficient space between the top of the cone and the inside of the shield to allow of the products of combustion passing downwards.

Mr. TEALE said it was intended to be sufficiently tight to prevent the products of combustion from falling.

Mr. ATKINSON asked if one could see whether the top gauze was on through the ventilating hole?

Mr. TEALE said they could get at it diagonally; but no parallel current would have influence over the top of the lamp.

Mr. ATKINSON thought it would be an advantage if one could see that the small cap was on after the lamp was put together.

Mr. TEALE observed that if the inner gauze was not in place, it would immediately show that everything was loose. The lamp ought to be examined before the top was put on.

Mr. RIGBY asked whether there would be any objection to making the tube $\frac{3}{8}$ inch longer, so that it would raise the cap?

Mr. TEALE said it was important that they should not have the gas burning above the shield.

Mr. JOEL SETTLE said they had all seen the Marsaut and the Mueseler lamps with the bonnet or shield, and as an experiment a hole was made in the shield, and although it would stand a current of some 50 feet per second before the hole was made it became very unsafe after the hole was made. These experiments were conducted with a view of ascertaining if a hole could not be made to see the inner gauze. He had misgivings that this hole would be detrimental, because the ventilation would pass through at great velocity, and, assuming an explosion took place inside, might conduct it outside.

Mr. TEALE said he did not think the case in point was at all parallel, for if they took a Mueseler shield lamp they placed the hole in the centre to see that the gauze was there; and the hole in the shield gave an additional pumping power, as it were, increased the suction in the upcast shaft in the form of the chimney. Taking it with a double-gauze lamp they did away practically with the advantages of the shield, because they got a current acting upon the plain case in the inner gauze, which overcame the resistance of the gauze and passed through in a superheated state and caused ignition. But in this case they had no such condition of affairs. Whatever velocity they had it struck against the inner cone, and was thrown into the lamp, and would be attacked by the flame and the products of combustion. If they increased the combustion beyond a certain point they would extinguish the light. If they did pass it from the outer to the inner portion they would be in the same position as with the Marsaut or Mueseler lamp. On the other hand, they had greater safety with this principle than with the Marsaut or Mueseler lamp.

Mr. RIGBY said they all agreed that the Piston lamp was an improvement upon others, and he was very much pleased with it personally. Mr. Teale had intelligently and fairly answered all the questions which had been put to him. He proposed a vote of thanks to Mr. Teale for his explanations.

Mr. ATKINSON said that upon a cursory view of the lamp he thought it was a good one. He seconded the proposition, which was carried.

DISCUSSION UPON MR. E. B. WAIN'S PAPER ON "THE THORNEBURRY SAFETY-LAMP."

Mr. TEALE said there was a difficulty in burning paraffin oil in the Thorneburry lamp. The lamp was in so many parts and was so complicated that it was difficult to keep the whole of the parts in order. It had been tried very largely, and so far as the light was concerned, it was admirable, and its safety was good.

Mr. ATKINSON said these were very important points.

Mr. TEALE said they wanted something practical for all purposes, and that was where the Thorneburry failed.

Mr. BRIDGETT said he had some of the lamps in use and they gave every satisfaction. They were used at junctions and they gave a splendid light.

The meeting then terminated.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, NOVEMBER 5TH, 1892.

MR. J. B. SIMPSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY reported the proceedings of the Council, and said that the question of lighting the Wood Memorial Hall and lecture-room by electricity had been referred to a committee.

The following gentlemen were elected, having been previously nominated :—

HONORARY MEMBER—

Prof. HENRY STROUD, D.Sc., Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

Mr. ALEXANDER MATHIESON, Colliery Manager, Hetton Colliery, Carrington, near Newcastle, New South Wales.

Mr. CLAYTON E. J. MITCHELL, Civil Engineer, 27, Mosley Street, Newcastle-upon-Tyne.

Mr. JAMES NEWTON, Colliery Manager, Whitehaven Colliery, Whitehaven.

Mr. GEORGE OLDHAM, Engineer, 25, Western Hill, Durham.

Mr. T. A. TATE, Colliery Manager, Bunker Hill, Fence Houses.

ASSOCIATE MEMBERS—

Mr. GEORGE BLAXLAND ATKINSON, Timber Merchant, Maritime Buildings, Quay, Newcastle-upon-Tyne.

Mr. J. P. CORNETT, Managing Director, Ford Paper Works, Hylton, Sunderland.

Mr. ARTHUR PATRICK DODDS, Iron Merchant, 13, Dean Street, Newcastle-upon-Tyne.

Mr. CLAUDE BOWES PALMER, Assistant Colliery Manager, Usworth Colliery, Washington, R.S.O.

ASSOCIATES—

Mr. THOMAS BERRY, Overman, Bagnall's Houses, Swalwell, R.S.O.

Mr. ROBERT CARR, Under Manager, Usworth Colliery, Washington, R.S.O.

Mr. WILLIAM SEVERS, Under Manager, Beamish View, *via* Chester-le-Street.

STUDENTS—

Mr. WILLIAM HENRY MASCALL, Mining Student, 27, South Church Lane Bishop Auckland.

Mr. GEORGE WALL, Mining Student, South Church, Bishop Auckland.

The following gentlemen were nominated for election:—

MEMBERS—

Mr. A. D. DIXON-BROWN, Electrical Engineer, 27, Mosley Street, Newcastle-upon-Tyne.

Mr. P. S. REID, Mining Engineer, 20, John Street, Adelphi, London, W.C.

Mr. CEDRIC VAUGHAN, Managing Director, Hodbarrow Iron Ore Mines, Millom, Cumberland.

ASSOCIATE MEMBER—

Mr. ALFRED ALLHUSEN, Managing Director, Newcastle Chemical Works, Musgrave House, Gateshead-upon-Tyne.

ASSOCIATES—

Mr. JOHN BUGLASS, Colliery Manager, Stobswood Colliery, Acklington, Northumberland.

Mr. FRANK HOWES, Under Manager, Singareni Colliery, Hyderabad, Deccan, India.

Mr. CHRISTOPHER HUNTER, Engineer, Broomhill Colliery, Acklington, Northumberland.

Mr. SIMON PEDELTY, Engineer, Clara Vale, Ryton-upon-Tyne.

Mr. JOHN GLADSTONE RAMSAY, Deputy, Page Bank Colliery, Willington, Co. Durham.

DISCUSSION UPON MR. W. COCHRANE'S PAPER "ON A DUPLEX ARRANGEMENT OF CENTRIFUGAL VENTILATING MACHINES."*

Mr. COCHRANE said he had nothing to add to his paper, but he thought it was understood, when the discussion on it was adjourned, that Mr Wallau would submit a communication on the subject.

Mr. THOS. BELL asked if there was a Capell fan working at any neighbouring colliery with the exception of that at East Howle?

Mr. M. WALTON BROWN thought not.

Mr. COCHRANE said that there were some large Capell fans working in Germany.

Mr. M. WALTON BROWN said that the report of the Prussian Fire-damp Commission showed that ventilating fans in Germany rarely gave more than 18 per cent. of useful effect. Prof. Bedson was translating this report for the Institute, and it would shortly be published.

* *Trans. Fed. Inst.*, vol. ii., page 483.

Mr. COCHRANE said high results were claimed for the Capell fan. Of course a good deal depended on the conditions of the experiments; he understood that fan was dealing with volumes of 100,000 to 250,000 cubic feet of air per minute under 6 inches of water-gauge.

Mr. A. L. STEAVENSON said the inventors of fans were apt to deceive themselves, and each one got more wonderful results than another. He recently went to Sheffield to assist in taking the measurements of the air and water-gauge in testing a fan, but he was certain that the measurements of air were too large, and consequently the results could not be accepted as correct.

DISCUSSION UPON MR. R. S. WILLIAMSON'S PAPER ON "THE CHANDLER FAN," AND MR. M. WALTON BROWN'S PAPER ON "THE RATEAU VENTILATOR."*

Mr. M. WALTON BROWN said the results of the experiments recorded in these papers on the Chandler and Rateau ventilators emphasized the importance of the trials being made with every precaution to obtain accuracy under similar conditions. The efficiency of the Chandler fans varied from ·57 to ·70, and there were no means of accounting for this material difference. The experiments on the Rateau fan were made by Mr. de Castelnau. One did not like to say they were altogether wrong, but as the mechanical efficiency varied from ·46 to ·72, it proved that the mode adopted of measuring the air at the top of the expanding chimney was not satisfactory.

Mr. COCHRANE enquired whether Mr. Brown thought that the Rateau ventilator was as efficient a machine as the other ventilators with which he was acquainted ?

Mr. M. WALTON BROWN replied that he brought the experiments upon the Rateau fan before the members of the Institute as being made on a fan for which a high efficiency was claimed, but he did not think it was more efficient than others of similar dimensions.

Mr. R. S. WILLIAMSON wrote in reply to Mr. Walton Brown's remarks upon the different efficiencies of the two Chandler fans that he experimented upon, that both fans were of the open-running type. The horizontal engine of 13 inches diameter and 26 inches stroke was suitable for 30 indicated horse-power, and, with this load, would absorb at least 10 per cent. of the power in friction; including the belt the 10 feet fan absorbed 21·13 indicated horse-power, and the 6½ feet fan 15·17 indicated horse-power, consequently, therefore, the engine and belt friction at this

* *Trans. Fed. Inst.*, vol. iii., page 171 and page 410.

light load was about 20 per cent. The mean effective pressure in the cylinder when the engine was indicating 21·13 horse-power was only 11·5 lbs. per square inch, and it is clear from this fact, that the engine could not run with less than 15 per cent. of frictional resistance when indicating 21·13 horse-power, therefore, when indicating 15·17 horse-power the frictional resistance could not be less than 20 per cent.; and both fans would give much higher efficiencies, with smaller engines, working at their full power. It is an established fact that engines work with the same frictional resistance with either heavy or light loads, and that the friction does not increase with the load. The friction of engines is practically constant at all reasonable loads, which accounts for part of the loss of efficiency in the small fan, say to the extent of 5 per cent. Further, the small fan had not such well-formed blades as the 10 feet fan. The space of brickwork round the blades was not so large, and the air did not pass away so freely, which would account for a further decrease of efficiency in the small fan. The fans still continued to afford entire satisfaction, and had not cost a single penny for repairs since starting. The inventor had, since the reading of the writer's paper, made several larger fans, which have given great satisfaction.

DISCUSSION ON MR. M. WALTON BROWN'S PAPER ON "THE KÖNIG DIFFERENTIAL WATER-GAUGE."*

Mr. M. Walton Brown exhibited a König water-gauge coupled with an ordinary type of water-gauge. He had been able to try the König water-gauge on a fan drift in comparison with an ordinary water-gauge. The great advantage of the König water-gauge, in addition to its giving an exaggerated scale of say 9 to 1, was the fact the readings were more easily taken, owing to the comparative steadiness of the fluid, as compared with the fluctuations in the levels of the water in an ordinary gauge, and this allowed of much more than nine-fold accuracy in the readings.

DISCUSSION UPON MR. W. N. ATKINSON'S PAPER ON "THE REPORT OF THE AUSTRIAN FIRE-DAMP COMMISSION."†

The Secretary read several portions of the paper to which the author desired to draw especial attention.

Mr. Thos. Bell (H.M. Inspector of Mines, Durham) said that the quantity of air per person recommended by the Austrian Commission was

* *Trans. Fed. Inst.*, vol. iii., page 452. † *Ibid.*, vol. iii., page 531.

far below the quantities employed in this country. In Durham—in the coal-mines of his district—the annual returns for the past year showed that there was on average 347 cubic feet of air per minute circulating in these mines per person employed underground; and 420 cubic feet per minute in the Cleveland ironstone mines. These figures did not, however, take into account the number of horses and ponies employed, but allowing for these, the ventilation of the mines in his district was very far in excess of the recommendations of the Austrian Commission.

The PRESIDENT said the figures given in the paper (70 cubic feet where little fire-damp was produced, 105 cubic feet for the second class where there was a moderate amount, and 140 cubic feet in the third class) were only recommendations; the actual state of things was possibly worse.

Mr. M. WALTON BROWN thought the recommendations were made in order to provide against the use of an excessive volume of air on account of the alleged dangers which might arise from the action of larger volumes of air in drying coal-dust.

Mr. SIMON TATE said there was a reference in the paper to the fact that 20 per cent. more air was found in the returns than in the intakes. Was that due to the expansion of the air in the mine or to the addition of gas?

The PRESIDENT thought it would be unnecessary to bring the paper before another meeting. It was a record of the work of the Austrian Commission, and it would not be necessary to discuss it further.

DISCUSSION UPON MR. W. HY. CHAMBERS' PAPER ON "THE PUMPING APPLIANCES USED IN THE SINKING OPERATIONS AT THE CADEBY NEW WINNING."*

Mr. A. L. STEAVENSON thought that the simpler they could have everything for use in sinking pits the better it would be. His impression was that they could have nothing simpler under usual circumstances than the old system of horizontal engine with quadrants.

The PRESIDENT agreed with Mr. Steavenson. He had had the discomfort recently of dealing with 2,000 gallons of water per minute at a depth of 50 fathoms; and he had been able to overcome this feeder with a 24 inches set of pumps worked by bell cranks. There would scarcely have been room in the shaft to have dealt with this quantity of water by Mr. Chambers' system. The paper would have been more interesting and useful if it had given some account of the cost of the system described; it was questionable whether, all things considered, the old system would not have been cheaper and more efficient.

* *Trans. Fed. Inst.*, vol. iii., page 513.

Mr. W. C. BLACKETT said no doubt portable steam-pumps had been successful in certain cases, where all the pipes and even the pump itself came in for other purposes afterwards.

Mr. T. E. FORSTER said he thought Mr. Chambers' principal reason for adopting the system described was the extreme badness of the ground; he dared not place a heavy engine on the top.

Mr. W. COCHRAN CARR wrote that he had been using a Denaby sinking pump with a steam cylinder of 22 inches diameter and 36 inches stroke, with a double-acting ram of 13 inches diameter. He regretted that this pump had not been working long enough to give a definite opinion about it, but so far it had worked satisfactorily, and was the best direct-acting pump of its sort he had seen. The following were its strong points in his opinion: —(1) It occupied little room in the shaft, and had the clacks, steam-chest, pipes, etc., so placed that when suspended it hung quite plumb; (2) it had large valve area, which enabled it to make a greater number of strokes per minute with less vibration than other pumps of the same stroke; (3) in case of necessity it would work with the cylinder submerged to a depth of several feet, even when exhausting direct into the water; (4) the general arrangements of the steam-chest and valves were satisfactory, there being no position which the piston could occupy in which it would not start, even if under such circumstances as described in the third remark; (5) the first joint next to the pump for water and steam was expansive, and allowed for any movement and prevented the breakage of pipes, which he thought had always been a difficulty with other pumps of similar kinds; and lastly the Denaby pump did not take as much steam as an Evans pump which was used in the same shaft, although the former was an inch larger in diameter of cylinder, the stroke being the same in each. He regretted that he had not had more experience with it, so as to give details as to the quantity of water actually pumped, and to compare its work with the Evans pump working in the same shaft.

Mr. W. HY. CHAMBERS, in reply, wrote that he concurred with Mr. Steavenson's opinion that the more simple everything could be made for use in sinking pits the better it would be. Having had extensive experience of direct-acting pumps and also of the old system of pumping with horizontal engines, working quadrants, the comparison in his opinion was very largely in favour of the more recent system, which was accompanied with marked simplicity. He did not stand alone in this opinion, as, since its introduction at Cadeby, the method had been adopted very extensively in preference to the old-fashioned system, and there are now, to the writer's knowledge, no less than nine different

kinds of pumps on this principle, or as near as can be without infringing on the patent rights of Messrs. Bailey & Co. The first ones of the same style were made by Messrs. Evans, of Wolverhampton, for the Griff Colliery, after Mr. E. Bainbridge and Mr. Melly endeavoured to make terms with the Denaby Company for hiring the pumps which were then done with. Mr. Melly wrote an article some time ago to the *Colliery Guardian* expressing his perfect satisfaction with the principle adopted; and with one or two exceptions this had generally been the case wherever the system was tried. With regard to Mr. Simpson's remarks, stating that he had no difficulty in dealing with 2,000 gallons of water per minute at a depth of 50 fathoms with a 24 inches set of pumps, and that there would scarcely have been room in the shaft to have dealt with this water by the newer system; the fact was that four times that amount of water was elevated from a depth of 60 fathoms by that system, and any one would have understood the position if four 24 inches sets of pumps had to be worked in a 16 feet sinking shaft, and the impossibility of putting in tubbing while they were working. With regard to the cost of the system described, the whole of the machinery, including pumps and pipes, was sold at a discount of not more than 10 per cent. This loss and the cost of replacing breakages was under £1,000. The labour employed in working the pumps was a fitter at 6s., a boy at 2s. 6d., and the man at the capstan-engine at 4s. per shift. The banksmen assisted the fitters to build up pipes on the top as required, when the pumps were lowered, and this entailed no extra cost. Mr. T. E. Forster's surmise was quite correct, that the principal reason for adopting the system described was the unfitness of the ground to carry heavy weights, necessitating the striking out a new line to cope with the difficulty. The writer could only say, after experience of both methods, that if any similar work be entrusted to his direction, and were the ground to be as bad as in this instance, or good enough to enable heavy lifts to be used, he would never of his own free will resort to such a costly, clumsy, and dangerous system as the placing of such tremendous weights of useless metal, as necessitated by the old-fashioned, and soon to be obsolete, system of lifting water in sinking pits by means of spear-rods and buckets, with its heavy train of strong gearing, engine, and powerful capstans, which were almost invariably consigned to the scrap heap, and sold as old iron on the completion of the work.

There being no further remarks offered, the meeting terminated.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 10TH, 1892.

MR. J. B. SIMPSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the previous General Meeting, and reported the proceedings of the Council. The agreement with the North-Eastern Railway Company as to the use of the passage adjoining the lecture-theatre had been sealed. Arrangements were being made for the electric-lighting of the Wood Memorial Hall and the lecture-theatre, etc.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. A. D. DIXON-BROWN, Electrical Engineer, 27, Mosley Street, Newcastle-upon-Tyne.

Mr. P. S. REID, Mining Engineer, 20, John Street, Adelphi, London, W.C.

Mr. CEDRIC VAUGHAN, Managing Director, Hodbarrow Iron Ore Mines, Millom, Cumberland.

ASSOCIATE MEMBER—

Mr. ALFRED ALLHUSEN, Managing Director, Newcastle Chemical Works, Musgrave House, Gateshead-upon-Tyne.

ASSOCIATES—

Mr. JOHN BUGLASS, Colliery Manager, Stobswood Colliery, Acklington, Northumberland.

Mr. FRANK HOWES, Under Manager, Singareni Colliery, Hyderabad, Deccan, India.

Mr. CHRISTOPHER HUNTER, Engineer, Broomhill Colliery, Acklington, Northumberland.

Mr. SIMON PEDELTY, Engineer, Clara Vale, Ryton-upon-Tyne.

Mr. JOHN GLADSTONE RAMSAY, Deputy, Page Bank Colliery, Willington, Co. Durham.

The following gentlemen were nominated for election :—

MEMBERS—

Mr. THOMAS ALEXANDER ALLAN, Consulting Mining Engineer, Brightlands, Richmond Hill, Surrey.

Mr. THOMAS BREAKELL, Mining Engineer, 92, Denmark Road, Greenheys, Manchester.

Mr. WALLACE THORNEYCROFT, Mining Engineer, 6, Dixon Street, Glasgow.

Mr. HENRY THOMAS WALES, Mining Engineer, Pontypridd, South Wales.

ASSOCIATE MEMBERS—

Mr. JAMES ERNEST BLENKIRON, Mining Engineer, West House, Arkengarthdale, Richmond, Yorkshire.

Mr. J. CARTMEL RIDLEY, Steel Manufacturer, 3, Summerhill Grove, Newcastle-upon-Tyne.

ASSOCIATE—

Mr. JOHN SPRY, Surveyor, Murton Colliery, *via* Sunderland.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, EDINBURGH, 1892.

The report of the proceedings of the Corresponding Societies Committee of the British Association was read, and the report of Prof. J. H. Merivale, the delegate of this Institute, as follows :—

NEWCASTLE-UPON-TYNE,
AUGUST 22ND, 1892.

TO THE PRESIDENT AND COUNCIL OF THE NORTH OF ENGLAND INSTITUTE.

DEAR SIRS,

I attended the two meetings of the Delegates of Corresponding Societies, held at Edinburgh on the 4th and 9th inst. There was a good muster, but there was very little on the agenda-paper of special interest to the North of England Institute of Mining and Mechanical Engineers. I had hoped to have been able to have brought before the meeting some report of the experiments of the Institute on Flameless Explosives, but the Durham strike has unfortunately prevented this.

The Earth-tremors' Committee have examined a large number of recording instruments, and a very simple form, designed by Professor G. Darwin, consisting essentially of a pendulum with double-suspension mirror is recommended provisionally. Professor Darwin has offered to lend and set up one of these instruments, and the Secretary of the Committee (Mr. Davison, an old student of the Durham College of Science) has agreed to look after it and observe its ways and manners at Birmingham during the ensuing year. If it answers the purpose, the Committee

will be in a position to finally recommend it in their report at the next meeting of the British Association at Nottingham. When this is done, a plan for a network of observing stations over the country may be elaborated.

The Underground Temperature Committee reported the observations made in an exceedingly dry borehole in America: where the rise of temperature was found to be 1 deg. Fahr. per 86 feet, a slower rise than usual. The borehole was one made by the American system, which brought up no core; an accurate section therefore could not be obtained, a matter of some importance in this connexion. The boring was to be continued to a depth of 6,000 feet for scientific purposes, and would then, I believe, be the deepest borehole in the world.

Yours faithfully,

JOHN H. MERIVALE.

INTERNATIONAL ENGINEERING CONGRESS, CHICAGO.

A letter was read from the General Committee of the Engineering Congress, inviting the members of the Institute to attend the Congress, which will hold its session from July 31st to August 5th, 1893, inclusive.

The Rev. G. M. CAPELL then read the following "Observations on Fans of Different Types working on the same Upcast Shaft."

OBSERVATIONS ON FANS OF DIFFERENT TYPES WORKING ON THE SAME UPCAST SHAFT.

By the Rev. G. M. CAPELL.

In 1884, when testing various types of fans, the writer was able to make a test of a Capell fan and a Guibal fan working under similar conditions on the same fan drift. The Capell fan was 5 feet in diameter, while the Guibal fan was 16 feet, but the results were not sufficiently clear to arrive at any definite conclusions.

One point was prominent, and this was recorded at the time, viz., that there was a different water-gauge in the Guibal fan when passing the same volume of air as the small Capell fan. Unfortunately the arrangement was removed, rendering further experiments impossible; but the writer made further tests on small fans, and found the same variation in a less marked degree.

There are now many Capell fans working on collieries, replacing large Guibal fans, and other types; and the observations of others on some of the principal of these fans may be now usefully recorded.

The point of the early tests at Homer Hill colliery comes out very clearly, and the lower gauge, for a given work in air, shows itself wherever the Capell fan has replaced a Guibal fan. There is only one case of a Capell fan and of a Schiele fan on the same shaft, and the difference in gauge has been fully noted in Mr. Maurice Deacon's account of his observations on a Capell fan and a Schiele fan working under similar conditions, at Shirland colliery, where the Capell fan showed the same low gauge for a given volume of air.*

The new type of Capell fan differs entirely from anything in use before, consisting of two distinct fans built up into one, so that the air of

* *Trans. Fed. Inst.*, vol. i., page 287.

the first is discharged into the second, its *vis viva* being destroyed by expansion into the larger area, under greater water-gauge, by reason of the greater velocity in the outer fan. The writer maintains that the action of the two machines, in dealing with air, is similar to that of a compound engine dealing with steam. The double arrangement gets more work out of the steam. But work in a fan is, to a great extent, the *vis viva* of the air, and if this is used up there is more effective work got out of the Capell machine; just as the slow, soft discharge from a compound engine, as compared with the rapid noisy discharge of a simple high-pressure engine tells us that more work has been taken out of the steam. Prof. Guibal got the right idea in his évasée chimney, but if the discharge of six revolving évasée's can be obtained, which is the point aimed at in the construction of the Capell fan, a still higher result may be expected than can be had with a fixed expanding chimney.

When the writer is asked how he can account for the differences shown, he answers that he has noted that some fans give more local action in gauge than others, *i.e.*, have a higher gauge near their inlets, but that extra gauge is not effective at a distance from the fan.

The writer remembers a case at a colliery near Birmingham, where a small Schiele fan, under 1 inch of water-gauge, produced 21,000 cubic feet of air. A large Guibal fan was put on, and with 1 inch of water-gauge gave about 35,000 cubic feet of air. On enquiry the writer found that, whereas the small fan gave about 0·50 inch of water-gauge at the bottom of the deep shaft, the large fan gave very little less water-gauge than on the surface. This fact points to the possibility of a variation in volume for gauge where there is a fan of large exhausting capacity, capable of throwing its gauge a long way back into the mine.

The first comparative tests that the writer will give of a Capell fan and Guibal fan will be those at the Prosper I collieries, near Borbeck, in Westphalia. As the guaranteed effect was higher than had ever been before obtained in the history of fans, the writer had special precautions taken in the measurements of the air passed by the Guibal fan, and as will be seen, the writer at once took the guarantee up. The state of things was as follows:—There was a Guibal fan 40 feet 6¾ inches in diameter, and 8 feet 4 inches wide; the volume of air passing was 59,340 cubic feet of air per minute, under a water-gauge at fan of 3·15 inches, and the volume of air required was 116,490 cubic feet per minute. The gauge can be easily calculated by the square of the volumes—$59{,}340^2 : 116{,}490^2 :: 3{\cdot}15 :$ 12·13 inches being the gauge required for 116,490 cubic feet of air with the Guibal fan.

The tests of the Capell fan at the Prosper I colliery, conducted by Mr. G. Herbst, engineer to the Prussian Fire-damp Commission, came out as follows:—

	Ft.	Ins.
Diameter of the Capell fan	12	6
Width " "	6	0
Two inlets, each	7	3
Revolutions of engines	87·5 per minute.	
" of fan	323	"
Water-gauge in drift	10·7 inches.	
Cubic feet of air per minute	127,574	
Horse-power in air	214·9	
" of engines	384·6	
Useful effect	55·6 per cent.	

Taking the squares of the volumes from the Guibal fan, it is found that its water-gauge for 127,574 cubic feet would have been 14·5 inches, or 3·8 inches more than the Capell fan, or a difference of 78 horse-power in the air. The writer simply records the figures as given to him.

Another marked case was at the Gneisenau colliery, near Dortmund, also in Germany. The Guibal fan, 40 feet 6¾ inches in diameter, with a drift gauge of 1·60 inches, passed 60,010 cubic feet per minute. The writer was asked to give 105,900 cubic feet per minute at 200 revolutions. For this purpose he designed a double-inlet fan, 11 feet in diameter, 7 feet wide, with two inlets each 7 feet in diameter. The results came out as follows:—

Revolutions of fan per minute	168
Water-gauge in drift	1·70 inches.*
Cubic feet of air per minute	84,720

The results of trials of the two fans, at nearly the same water-gauge being:—

	Guibal Fan.	Capell Fan.
Water-gauge ...	1·60 inches	1·70 inches.
Volume ...	60,010 cubic feet.	84,720 cubic feet.

The gauge difference is obvious.

At Shirland colliery, the Schiele fan is 5 feet 3 inches in diameter, with double inlets; and the Capell fan, 12 feet 6 inches in diameter, with single inlet. Capell fan, 1 inch drift gauge—60,084 cubic feet. Schiele fan, 1 inch drift gauge—43,699 cubic feet. Capell fan, 3·25 inches drift gauge—118,241 cubic feet. Taking the squares of volumes, to get 118,000 feet, the Schiele fan would have required no less than 7·55 inches of water-gauge. These figures are not the results of the writer's own observations, as he has before stated.†

* The volume of air being very large in proportion to the fan's cubic capacity, the manometric effect is low.

† *Trans. Fed. Inst.*, vol. i., page 289.

At Coalpit Heath colliery, near Bristol, there are on the same upcast a Guibal fan, 16 feet in diameter and 5 feet 3 inches wide, and a Capell single-inlet fan, 12 feet in diameter, 5 feet wide, with inlet 7 feet in diameter The results came out thus:—

	Guibal Fan.	Capell Fan. (1)	Capell Fan. (2)
Revolutions per minute	120	150	223
Water-gauge (inches)	2·50	1·75	4·50
Mean air-speed in drift per minute (feet) ...	830	885	1,309
Area of drift (square feet)	50	52	52
Volume per minute (cubic feet)	41,500	46,020	68,068

The drifts were divided into squares with wires, and the anemometers were used for equal periods in each square. The above observations were taken by Mr. G. Hewitt and the late Mr. G. Nasmyth, of Coalpit Heath colliery.

The writer could give many other observations from German collieries, and when the paper is discussed he hopes to do so. All experiments show the same sort of variation in gauges required.

In conclusion, and for comparison, the writer gives the water-gauge of fan and furnace at Silverhill colliery belonging to the Stanton Iron Works Company.*

The furnace water-gauge taken below was 1·40 inches, and the mean volume at returns was 110,000 cubic feet per minute.

The Capell fan, 12 feet 6 inches in diameter, with two inlets 7 feet 6 inches in diameter, gave the following results:—

	(1)	(2)
Revolutions	123	132
Water-gauge (bank)	1·40	1·50
„ measured below, at same place as with furnace (inches)	1·30	1·40
Volume per minute at returns (cubic feet) ...	110,920	129,150

The shafts are each 400 yards deep and 15 feet in diameter. Apart from shaft friction, the fan gets more air than the furnace at the same water-gauge below ground; and an equal quantity at the same water-gauge in the drift, as with the furnace water-gauge below ground.

The writer's object is to give merely the results of his comparisons, and he does not propose to make any further remarks, but hopes to hear what others have to say upon the subject.

* *Trans. Fed. Inst.*, vol. ii., page 549.

Prof. A. S. HERSCHEL (Slough) wrote that it had hitherto seemed to be quite inexplicable to mining engineers (and he had been entirely at a loss till now for any—even weakly defensible—interpretation of the remarkable mode of action observed in double-chambered fans, of which Mr. Capell had produced in his paper from his experience with his fans, so many reliable examples) that weaker drift water-gauges are required with them than with single-chambered fans, or as compared with furnaces, to produce the same volume of air-current in one and the same mine's unchanged conditions of resistance. Although so seemingly impossible to reconcile with the theory that a thin-plate orifice's flow with *vena contracta* is a true equivalent of any such unvarying resistance, and that the relation of air-volume to water-gauge should therefore be as fixed as in the case of such an orifice, with whatever description of fan the water-gauge is produced which makes the current; yet that the contrary experiences from this are not the results of ill-made observations, or illusory determinations, was proved by the multiplied examples of such abnormal features which the comparisons of different fans, working on the same mine with each other, had during the last few years brought prominently forward. The singularity in question had indeed been for some time the theme of controversies among users of ventilating fans, ever since the first applications were made successfully on a large scale to mine ventilation, of the Capell double-chambered fan. At an early period of these experiments, in August 1889, Mr. Capell first compared together a Guibal fan and a Capell fan working on the same mine beside each other, at Coalpit Heath colliery, near Bristol. In that experiment, when a 16 feet Guibal and an 11 feet enclosed single-inlet Capell fan were run upon a mine together at the same speed (80 revolutions in a minute), for which it was found that the two fans working separately produced the water-gauge depressions in their drifts of 1·10 inch and 0·83 inch respectively, the Capell fan drew air from the mine, in spite of its low water-gauge, in a measurable current. At 88 and 90 revolutions of the Capell fan, while the Guibal fan contined to run at 80 revolutions, the conditions of proportion in the air-draughts were reversed, hardly any air-current then passing through the Guibal fan, although the water-gauge of the Capell fan in its drift, when working separately, only just attained 1·00 inch at 90 revolutions. This feature which the Capell fan was then found to show of excelling other fans in lowness of drift water-gauge, for a given air-volume on a given mine resistance, had been so frequently verified and confirmed by subsequent comparisons with other fans tested beside it on the same mine resistances, that the well-recorded

proofs of the peculiarity cited by Mr. Capell in his present paper are only a select few of the most certain evidences which had been very plentifully noted of the fan's very singular and abnormal-looking property. In the first published experiments made with the fan by Mr. D. K. Clark, in 1884, it exhibited, like a Guibal fan, nearly the full double-power water-gauge due to blade-tip velocity, at its air inlet. Calculating the horse power in the air by the ordinary formula, with this water-gauge and volume, it was found to exceed by many per cent. the amount of power used to drive the fan, proving (for this is all that can be concluded positively from the observation) that by a small permanent output of actual from latent energy, a considerable fraction of the air-current which passed through the fan was set flowing idly, or perpetually, as a companion stream to the main current, rather than drawn along the route by mechanical work against mechanical resistance. So far as the air's oblique impact, or dash against the fan's outer wing-blades, in spouting from the port-holes of the inner fan-chamber assists the fan-body's revolution, some partial measure of the air's volume may, in fact, be regarded as coursing through the fan in an endless circulation of closed stream lines, requiring no mechanical work to maintain their self-recuperative motion ; for just such streams, endlessly enduring flux and reflux of actual and potential energy of motion present themselves in fluid vortex-filaments as a kind of perpetual orbitation of fluid-matter rings round a core or region of relatively lower pressure than the encompassing retaining pressures prevailing in the surrounding body of the fluid mass. As the growth of physical knowledge has swiftly advanced with great strides in recent years, and as the need of placing energy and matter, in a rigid prosecution of all the sciences (and especially in the leading column ranks at the van of their advance, of the exact sciences) on an objective level of the study of nature with each other as the universal mind and body of nature's operations, has of late years grown to be strongly felt and very clearly recognized, this current flow of constant freedom and of permanent deliverance from mechanical propulsion in the companion current through the fan, may now easily be perceived to owe its franked liberty of passage through the fan's inlet-tube and chamber-channels to a double, or taking-and-return transaction of work performance and of work-resumption between the current and the driving-power, on the two sets of fan-blades fixed firmly to the driving axle; which compensating pair of work-compounding actions eliminates the power's concernment with the stream-flow, while it therefore also, at the same time, sets free the idle current from friction's drags against the inlet's sides

and the fan-chambers' wings and blades past which it races, which are all confronted singly and collectedly to the driving-power directly. The consumpt of power by friction in passing these obstructions is thus arrested undiscernibly in the same process with the two transaction-dealings with the driving-power which are performed visibly and observably in the fan's wing-blades and compartments; but the neutralization of the friction must not be expected to be an intelligible part of the two-fold taking-and-return procedure in the same way that two independent steps can be recognized and discriminated, by which the power itself is plainly dealt with in the operation, because although there are thus means to use power's dual shapes alternately, for self-compensation and economy no means are known by which the availability of driving-power can be recovered from its unavoidable wastes and losses here and there through friction. Although not actually a recurrent stream, in the sense of a whirling one with closed flux and reflux of actual and potential energy of circulation round a low-pressure core or vortex-axis, the idle-coursing current has yet a visibly reciprocating flux and reflux of its sensible and potential energy in its two-phased way of dealing with the driving power and at the same time also undiscernibly with the friction-checks opposed to it, which is just similar and equivalent in its rocking or reciprocating character between one of its two states of energy and the other, although not in any other respect identical in circumstances of its nature, with a fluid-vortex filament in continual orbitation. There is no idle-running companion air-stream through a Guibal fan, or through any kind of single-chamber fan, because these fans' constructions furnish no means for a taking-and-return transaction between such a current's energies and the driving power, on one side, nor, in consequence of this, can any part of the air-current through such a single-chambered fan free itself from frictional resistance on its route as a description of mechanical opposition which, when a fan's rate of revolution is uniform and constant, is directly and collectively confronted alone, or quite singly and indivisibly to the driving power.

Mr. T. A. SOUTHERN (Derby) wrote that he was very sceptical of the accuracy of the observations quoted in Mr. Capell's paper, or at any rate of their sufficiency as a basis for accurate and fair comparisons; nor did he agree with the writer's conclusions. He considered also that Mr. Capell's explanations of the discrepancies observed, by suggesting that fans (and the Capell fan in a special degree) had a strange and inexplicable knack of "throwing the water-gauge a long way back into the mine," was one which conveyed no clear idea, tended to confuse and

mystify the issue, and had no foundation in recognized laws relating to the motion of an elastic fluid, at uniform or varying velocities, in regular or irregular passages. Comparisons of ventilating appliances, if they are to be of any real value, must be based upon the averages of a long series of careful observations, in order to eliminate errors in the measurement of quantities, water-gauges, speeds, etc. In the last comparison given by Mr. Capell, viz., that between the fan and furnace at Silverhill colliery, he took the mean volume of air in the returns at 110,000 cubic feet per minute for the furnace, but this was not based upon any experiments, for he had shown* how these figures had been obtained, as follows:—"Mr. J. A. Longden, in a letter, gave the average quantity of air with the furnace at 1·4 inches water-gauge, as 110,000 cubic feet per minute. Mr. J. C. B. Hendy, in his tabulation (page 549, vol. ii.) in the *Transactions of the Federated Institution of Mining Engineers*, relating to the Capell fan at Silverhill colliery, puts the average work of the furnace there, with the same water-gauge, viz.:—1·4 inches, at 122,000 cubic feet per minute. But in a special measurement with 1·40 inches of water-gauge of the furnace (thermometer 52 degs. Fahr. on the surface, and 64 degs. Fahr. in the mine) he gave the writer as results 105,530 cubic feet of air per minute, measured in the returns. Therefore 110,000 feet may be taken as the mean result of the furnace ventilation with 1·4 inches of water-gauge on the doors below." Here is a comparison placed before the members, based upon the most haphazard data; an approximate statement by Mr. Longden, another by Mr. Hendy, one special measurement with a gauge of 1·40 inches, and then strike an average (as favourably as possible) and the thing is done. It is very difficult to read a water-gauge to within $\frac{1}{20}$ inch, but on this large volume of air $\frac{1}{20}$ inch error in the reading of the water-gauge would make a very great difference; consequently he thought that he was justified in saying, without any disrespect to the writer, that he had no faith in, and placed no reliance upon, any of the figures quoted by Mr. Capell.

Mr. J. S. WALKER (Wigan) wrote that he had for a long time ceased to take the water-gauge at the fan-inlet; it was now his invariable practice to take it in the fan air-ways, preferably near the top of the upcast shaft. When this was done, unless there was some unusual friction in the pit, there was not much difference betwixt the water-gauge taken in this position and at the separation-doors at the bottom of the pit. With reference to the comparative tests of fans, he considered that in the case of two fans being tested upon one pit, unless designed for the same duty,

* *Trans. Fed. Inst.*, vol iii., page 198.

the comparative efficiencies of the types obtained would not be reliable. The writer wishes to refer the members to Mr. Barnes' statement* of the work performed by a Walker-Guibal fan at the Grassmoor collieries, and confirmed by Mr. C. E. Rhodes. The efficiency of the Guibal fan is now so well recognized, that it is not at all likely to be prejudiced by such comparisons as appear in Mr. Capell's paper. It would be instructive if Mr. Capell would inform the members, on what lines the fan at the Prosper I colliery, Westphalia, and that at the Coalpit Heath colliery, near Bristol, were constructed, and by whom?

Mr. M. Deacon (Alfreton) wrote respecting Mr. Capell's calculation that the Schiele fan at Shirland would have required not less than 7·55 inches of water-gauge in order to have produced 118,000 cubic feet of air per minute was theoretically correct, but it must be borne in mind that the fan was doing its maximum work at 1 inch water-gauge when it produced 43,699 cubic feet per minute. Although the experiments made upon the two fans were, in the writer's opinion, comparative at 1 inch of water-gauge, beyond that point he did not think that any calculation could be considered as fairly comparative. It would be interesting if Mr. Capell would describe the exact position of the orifice of the water-gauge tube and its direction in relation to the inlet of the fans in the Coalpit Heath experiments.

Mr. A. L. Steavenson (Durham) said no one had a greater admiration than he had for the way Mr. Capell had worked out his observations, and he would be pleased to see his efforts crowned with success. At the same time he agreed with some of Mr. Southern's observations as to the experiments being too fragmentary. What they wanted was a series of observations taken by persons whom they could trust. He did not mean to say they could not trust Mr. Capell, except in the respect that he had perhaps a little bias for the results of his own fan, naturally, and some people had accepted his conclusions. Mr. Capell said in his paper that "one point was prominent, and this was recorded at the time, viz., that there was a different water-gauge in the Guibal fan when passing the same volume of air as the small Capell fan;" this was a question of fact which should be thoroughly tested. A great deal depended on where the water-gauge was taken. He could understand that Mr. Capell would get a higher water-gauge at a distance from the fan than some of the smaller fans, such as the Schiele. Mr. Capell had said that his fan had six évasée chimneys in which it resembled the Guibal fan, but from the effects obtained he (Mr. Steavenson) rather doubted the resemblance. Unfor-

* *Trans. Fed. Inst.*, vol. ii., page 224.

tunately, they had only one case given in which they could test the manometric efficiency of the Guibal fan. Mr. Steavenson then referred to the results of numerous experiments in which the Guibal fan gave a manometric efficiency of at least 0·62. None of the open-running fans reached 0·50, simply because they had not an évasée chimney; if the Capell fan had six évasée chimneys the results should be very much higher than the 0·46 to 0·48 given as the average manometric efficiency. The paper only recorded the results of the trial of one Guibal fan of 16 feet diameter, giving 0·65, and here there was a manifest difference between the Guibal fan, which was 0·65 and the Capell fan which was only 0·48. The single case in which the Capell fan gave the manometric efficiency of 0·52 seemed to be wrong, as in none of the others did it attain 0·50. Hitherto it had been claimed that the Capell fan gave upwards of 68 and 70 per cent. of useful effect; now they had got down to something reasonable, and the Prosper I colliery fan was quoted at 55 per cent.; this was a very large reduction, but it was still an exceedingly good result, and he hoped the Capell fan would never yield less.

Mr. Capell said that result was obtained with 10·70 inches of water-gauge.

Mr. Steavenson, continuing, noticed that Mr. Capell had read another paper some time ago, but it was of so fragmentary a character that it was impossible to follow it.* They could not go into the question of volumes and water-gauges without a long series of accurate experiments. Mr. Capell had many volumes of experiments, but they were all taken in the same way and he feared they were not sufficiently reliable. He hoped, however, that before long they would have a Capell fan in this district, and have it thoroughly tested.

Mr. T. H. M. Stratton, following up the remarks of Mr. Steavenson, said the manometric efficiency of the Capell fan varied very largely. At the Prosper I colliery it was 0·50, at Gneisenau colliery 0·40, at Coalpit Heath colliery 0·43, and 0·50 at the higher speed, and at Silverhill colliery it was 0·43. There was a variation from 0·40 to 0·50, whereas in all other fans which he had tested the manometric efficiency was consistent and constant, in the Guibal being about 0·65, and in the Capell, Schiele, and Waddle, 0·46.

Mr. M. Walton Brown (Newcastle-upon-Tyne) said he presumed that Mr. Capell was alluding to the experiments upon the fans at Homerhill colliery when he said that "one point was prominent . . . . that

* *Trans. Fed. Inst.*, vol. iii., page 196.

there was a different water-gauge in the Guibal fan when passing the same volume of air as the small Capell fan." These experiments may be recalled, together with the 1867 experiments upon the same Guibal fan :—

Description of Fan.		No. of Experiment.	No. of Revolutions per Minute.	Volume of Air per Minute. Cubic Feet.	Water-Gauge. Inches.
Capell fan (5 feet)		1	535	14,128	1·00
		2	412	11,171	0·50
		3	450	21,600	0·50
Guibal fan (16 feet)	1869	1	26	13,600	0·15
		2	65	37,500	1·02
		3	96	51,700	1·75
"	1885	1	—	9,288	0·50
		2	82	11,412	1·00
		3	93½	14,508	1·50

The 1885 experiments upon the Guibal fan might be discarded, and a comparison of the 1869 experiments showed that the Guibal fan produced a very much larger volume of air than the Capell fan running at the same water-gauge, viz., 37,500 cubic feet at 1·02 inches by the Guibal fan against 14,128 cubic feet at 1 inch by the Capell fan. The Homerhill and Shirland collieries' experiments proved conclusively that in each instance the fans were much too small and "inappropriate" to the resistance of the mines in question. Both were running under unfavourable conditions, and the resistances of the small fans to the passage of the air necessarily reduced the results. As to the action of the Capell fan, he (Mr. Brown) thought it was much the same as other fans of similar dimensions, producing a certain water-gauge at their inlets which was decreased if the readings were taken at increased distances from the fan. It was a recognized fact that a large fan would produce the same volume at a certain water-gauge when running at a lower speed than a small fan, thus :—

Description of Fan.	Diameter of Fan. Feet.	Revolutions of Fan per Minute.	Speed of Rim of Fan per Second. Feet.	Water-gauge. Inches.	Volume of Air of per Minute. Cubic Feet.
Guibal fan	30	65·0	102·1	2·883	100,000
"	16	171·7	143·8		
Waddle fan	30	69·2	108·7		
"	16	184·1	154·2		
Schiele fan	12	224·2	140·9		
"	10	322·2	168·7		

He (Mr. Brown) would like information as to the mode in which the water-gauge readings at the bottom of the shafts, referred to in Mr. Capell's papers, were made; and also as to how a "fan of large exhausting capacity" can throw its water-gauge into the mine. If the water-gauge was correctly observed under precisely the same conditions at the

bottom of the upcast shaft leading to the ventilator, he could not understand how, if the water-gauge at bank was constant, that the water-gauge below ground was found to be less when one fan was running than with another; and all practical experiments coming under his observation support this view. He had made experiments, and found that the water-gauge at the bottom was practically constant under the same conditions. From the Appendix to the Report of the Prussian Fire-damp Commission (vol. v., pages 62 and 63), he found that the Guibal fan at the Prosper I collieries, No. 1 Pit, was 39 feet 4·45 inches in diameter at the tips of blades, and produced, at 50 revolutions per minute, or a blade-tip speed of 103·8 feet per second, 45,900 cubic feet of air per minute under 2·756 inches of water-gauge, the useful effect being only 0·202, at a manometrical efficiency of 0·58. Considerable improvement must have been made, and the resistances of the mine considerably decreased, in order that the same fan should produce, at a later date, 59,340 cubic feet of air, under 3·15 inches of water-gauge. It was very certain that an equal amount of improvement had been effected prior to the erection of the Capell fan, the equivalent orifice having been enlarged from 10 and 12 square feet for the Guibal fan to over 14 square feet for the Capell fan. He would also like to know the lines upon which this Guibal fan was built, and who was the maker, as there must be something to account for the low mechanical efficiency of 0·202.

Prof. H. STROUD (Newcastle-upon-Tyne) said that the given water-gauge did not indicate the true difference of pressure, as was evidently shown by examples taken from the paper. He should not imagine the same difference of pressure would give any different volume of air whatever the fan used, provided always that the circumstances were identical as to the resistance to air-flow in the mine.

Mr. A. L. STEAVENSON (Durham) said that, with respect to "throwing back," no doubt with different fans they would find a different vacuum at distances from the fan where they had insufficient area for the air to flow through, and he thought it was not a question of "throwing back" but of "swallowing" the volume. Of course the vacuum would be farther back with one fan than another, but "throwing the vacuum back" was rather an unhappy expression.

Mr. M. WALTON BROWN said with regard to taking the water-gauge at the bottom of the pit, it seemed to him that the correct way to do so was to carry a tube from bank. If the water-gauge was taken on the separation-doors the result would only be the difference of density on the two sides of the doors.

Mr. J. HODGSON (Edmondsley) asked whether Mr. Capell intended them to understand that one fan could exhaust more air than another at the same water-gauge: that is to say, suppose they obtained 50,000 cubic feet of air per minute with 1 inch of water-gauge at bank with the Guibal fan, would the Capell fan produce the same volume on the same mine at less than 1 inch of water-gauge; and were they to understand that they would get the same volume of air with a less water-gauge by the Capell fan?

The Rev. G. M. CAPELL (Passenham), replying to the discussion, first referred to Prof. Herschel's communication, which suggested a difficult line of thought. The nearest approach to it he could think of was its relation to the phenomena of the flow of the electric current. Referring to the more practical points raised he did not think any one present had been put in possession of a certain fact, viz., that the Capell fan, when it was run to produce initial gauge, closed off from the air altogether, gave a higher result than the Guibal fan. Mr. Howe in a paper before the Chesterfield Institute in 1871 stated that "the Staveley fans have been frequently run under different conditions for the sake of experiment, and whether the air is conducted through miles of pit roads, before reaching the fan, or simply exhausted from the atmosphere close to the inlet without passing through the pit at all, or if the air is effectually shut off from it and the ventilator turned round without any discharge, there does not appear to be any appreciable difference in the water-gauge indications for the same velocity of tips." The design of each Capell fan was different to any other, as he tried to apply each one to its special work. The following trials had recently been made upon the Guibal and Capell fans at the Marles collieries, in the north of France:—

	Guibal Fan.	Capell Fan.
Fan, diameter	23 feet.	12½ feet.
„ width	—	9 „
„ diameter of inlets ...	—	7 „
Engines, cylinders	—	2
„ diameter	—	26 inches.
„ stroke	—	52 „
„ fly-wheel, diameter	—	20 feet.
Revolutions per minute, engine	75	61·5
„ „ fan	75	305·0
Water-gauge, near fan ...	1·40 inches	9·60 inches.
„ in main drift ...	1·00 „	9·20 „
„ in a side drift	—	9·00 „
Volume of air per minute	63,540 cubic feet.	180,000 cubic feet.
Horse-power in air	13·12	272
Indicated horse-power of engine	32·23	480
Mechanical efficiency	0·407	0·578
Manometrical efficiency ...	0·348	0·547

He advocated the static water-gauge as being the only one which would give true comparative results. There were certain conditions of a mine which they had not yet been able to find out the cause of, where neither one fan nor another would give its full useful effect.

Mr. A. L. STEAVENSON asked if the water-gauge had ever been tested on both the inner and outer cases?

Mr. CAPELL said they had, and the water-gauge taken upon the outer fan was always higher than that upon the inner fan. The object of the outer chamber was to decrease the resistance to the discharge of the air from the mine. They were all aware that there was no water-gauge visible when they had natural ventilation; it was not until they got past the speed of the natural ventilation that the water-gauge began to be visible. With regard to Mr. Southern's observations as to Silverhill colliery, he (Mr. Capell) could only say that he had never himself experimented in the fan-drifts or returns at this colliery. The results of the experiments were given to him by the two gentlemen as having been carefully taken. The water-gauge was fixed between the separation-doors in the pit, and in this position was common to the furnace and the Capell fan. There was no attempt at comparison, because the furnace observations were made just before the fan stopped, and he himself had had no opportunity of verifying the results, but the ventilation-books of the mine showed that the figures he arrived at, as the general results obtained by the furnace, were very fair ones. With regard to the improved condition of the resistance of the mine at Prosper I colliery, he could only say that the Prussian Fan Commission reported in 1884, and Mr. Herbst's report was made at the beginning of 1890; and it was quite possible that the conditions of 1890 were not those of 1884. But the Guibal fan was still on the mine and was run, alternately with the Capell fan, when it was first started in work. In using the words "throwing back," he only quoted from Mr. Deacon's paper. They would find in that paper that whereas, at the bottom of the downcast shaft, the water-gauge of the Capell fan, with 1 inch at the surface, was very slightly altered, that of the Schiele fan, at the same point below, was only 0·45 inch. He used the term to show that there was a fictitious gauge which did not affect the mine. If all experiments were made with the static gauge they would be able to compare one fan with another, and ascertain their actual ventilating powers on the mine. In reply to Mr. A. L. Steavenson's remarks that the Capell fan water-gauge was the same as the Waddle fan as to manometric efficiency, Mr. Capell cited the case of a 12 feet single inlet fan at Crespin colliery, near Anzin, giving 7 inches of water-gauge at 240 revolutions per minute, or

0·70 manometric efficiency. The 10 feet fan at Waleswood colliery produced 3·10 inches of water-gauge at 210 revolutions, or 0·574 of manometric efficiency. The 12 feet single inlet fan giving 4·75 inches of water-gauge at 225 revolutions, or 0·535 of manometric efficiency. The three Guibal fans tested by the Mechanical Ventilators Committee of the North of England Institute, in 1878, gave 0·52 to ·56 of manometric effect. The Waddle fan at Celynen colliery gave 0·457, and Schiele fans 0·32 to 0·333, of manometric effect. The Capell fans are designed to give certain manometric effects, and they nearly all vary in this respect, according to the condition of workings. In reply to Mr. Walton Brown's remarks about the experiments at Homer Hill colliery. The mine was not in the condition of the previous experiments referred to, as the return was blocked to increase friction, and the downcast shaft was covered with boards and sacking for the same object. In the early experiments, and in the tests with the Capell fan, Mr. James Swindell was the observer, and first noticed the gauge and volume discrepancies. With regard to the remarks about accuracy of observations, he (Mr. Capell) merely gave figures handed to him by others. The same class of discrepancy running, though results coming from unprejudiced sources, widely distant from each other, all point to some peculiarity in the fans' action, which he should be only too glad to have explained. A constantly recurring phenomenon cannot be explained away by a mere supposition that observations were wrongly taken. If only one or two cases existed, it might be so, but with large numbers some other cause must be sought. In reply to Mr. A. L. Steavenson, he (Mr. Capell) regretted that he used an inappropriate expression if it was so, but when he found that the water-gauge at 500 yards from the pit bottom was 1 inch with one fan, and 2 inches at the same spot with another, the gauge at bank being the same, the result was as if one fan actually threw back its gauge farther into the mine than another, the result, no doubt, of its greater capacity for swallowing air rapidly than the other fan. The observations of Mr. Howe on the Staveley Guibal fan, to the effect that the gauge was always the same at the same speed, showed that the gauge tube was in the inlet of the fan, where increased volume through increased air-velocity kept the gauge constant, whereas the increase of air into a large fan drift always lowered the gauge in the drift away from the influence of the inlet: gauge and volume being the two sides of a balance, if you increase the volume largely at a given speed the gauge is lowered and *vice versa*, if the gauge tube is not placed in a position to register the increased air-velocity.

The PRESIDENT said the discussion would be adjourned pending the publication of Mr. Capell's paper and the correspondence it had elicited. He would, however, move a vote of thanks in the meantime to Mr. Capell, to whom they were all deeply indebted for his attendance that day, and for the information he had given them, and although he had been pretty freely criticized he would no doubt feel that this had been done in a friendly spirit and with the view of getting at the facts of the case.

Mr. A. L. STEAVENSON seconded the vote of thanks, and said that it certainly would not be Mr. Capell's fault if the members had not benefited by the paper.

Mr. CAPELL acknowledged the vote of thanks, and said he would only be too glad to render any assistance he could with the view of arranging and carrying out experiments, and to give such time as he could spare to the matter.

The following papers were taken as read, and the meeting adjourned.

GOLD-MINING IN BRAZIL.

By E. M. TOUZEAU.

Introduction.

The industry of gold-mining in Brazil belongs more to the past than to the present, and consequently any attempt at description must contain much which appears to be out of date, and as such only of historic interest.

If, however, some connexion can be established between the methods pursued in the past and the present decadence of a once important pursuit such reference will be seen to be pertinent to the subject of this paper.

Before the great gold-fields of California and Australia had monopolized an attention now shared by South Africa, Brazil occupied the foremost position as a gold-producing country. The greatest returns were made during the last century and the first half of this; during the former period by native enterprise and during the latter principally by that of English companies.

The history of gold-mining seemingly repeats itself in each country nay, in each field, with such a fidelity to detail that the mistakes made have borne a general family resemblance, and that of Brazil forms no exception to the rule. A period when gold is found plentifully at surface or in shallow workings is followed by the lavish and often ill-advised expenditure of capital. To this succeeds a stage of discredit when sound concerns suffer with unsound, only to be terminated by a gradual weeding out of the bad, and a prosecution of the good ventures on legitimate lines.

Brazil reached the discredited stage and stopped. Her history therefore lacks the completeness afforded by that of later gold-producing countries which have each found their check to have been a salutary lesson, leaving them the stronger for its learning.

With the knowledge gained in more recent fields, the advantages of modern machinery, and the better means of transport now afforded, Brazil may yet hope to give a good account of herself, and emerge from her present obscurity. During the years which have elapsed since English

mining enterprise almost ceased in Brazil, the methods and means of extracting and treating ores have advanced sufficiently to make the poor and unworkable property of that date a workable and payable one to-day.

Immense quantities of the surface-clays, sand, and gravels, the latter called by the natives "cascalho," were excavated and carried to the "corregos" (streams) to be washed for gold. Hydraulicking was not attempted as now known, but reservoirs were built and the hills contoured for miles with "regos" (ditches) to convey the water from them, or the streams intercepted, to some favoured site for washing. At such sites, sluices called "canoas" were either excavated out of the natural rock or built of wood, and upon the rough bottoms of the former or in the hides or baize (bietta) stretched on the latter the gold was arrested. Between Morro de Santa Anna and Passagem many of these rock canoas may still be seen, and the whole surface of the country for a considerable area has evidently been excavated and washed in this way.

Washing in the rivers and streams also produced a large amount of gold, and even now it is very common to see a native, knee-deep in the water, raking up the bottom with an "enchada" (hoe), so that the disturbed dirt may flow through the little race he (or she) has made and over a few pieces of bietta upon which he (or she) may hope to arrest a few particles of gold as a reward of his (or her) day's work. The yield of the streams improves after heavy rains.

It was a common practice in the slavery days to send out individual slaves on such a mission, taxed to bring in a vintem of gold in a quill as the minimum of a day's work—the receipt for a smaller quantity being often given to them on their backs.

The writer has been told by the proprietor of one large fazenda that grains of gold are at times found in the crops of fowls killed on his property, and he has himself washed very fair samples from the alluvial mud and sand of river-banks, which shows that the streams still derive a supply from the waste of the surrounding country.

On one property visited by the writer gold to the value of £60,000 had heen obtained from the outcrops of the reefs by the late Brazilian proprietor. Fires were lighted on the lodes, and when the rock became sufficiently heated cold water was thrown upon it. The rock thus broken was carried on mule-back about three quarters of a mile to stamps erected on the banks of a stream. The reefs are large, and must have been very rich at that time to cover so heavy a cost, and still yield such a handsome return.

At Ouro Preto, formerly called Villa Rica, innumerable small galleries were driven into the mountain-side, and small shafts sunk, from which an immense amount of mineral was extracted, and large quantities of gold obtained and, doubtless, also lost. For miles in an easterly direction the mountains are honeycombed by such shallow workings, and at Morro de Santa Anna 5,000 miners worked their separate claims or "datas" in a similar manner until the property passed finally into the hands of the Don Pedro North d'El Rey Mining Company, Limited.

The early Portuguese settler and his Brazilian descendants were wonderfully successful seekers of gold, but their mining knowledge was very limited; and water once reached, their works had to be abandoned.

In the early part of the present century English capital began to flow into Brazil, until at one time a number of properties were being worked and managed by English companies. Foremost amongst these was the Imperial Brazilian Mining Association, which will be again alluded to, the St. John d'El Rey, the Don Pedro North d'El Rey, and others.

They had great difficulties to contend with in bringing machinery and stores over long distances, in a country where, as yet, railways were unknown, and everything had to be conveyed in bullock-carts or on mule-back over an interminable series of the roughest mountain-roads.

Despite many drawbacks, mining was prosecuted and a very large amount of gold sent home, while the vigour of some of these undertakings is evinced by their continued existence to the present day.

This, the historical portion of the subject, might almost conclude the paper if its title were strictly adhered to, for little has been done in recent years to develop one of the greatest mineral districts of the world—a neglected and in part a forgotten one.

Mr. Henri Gorceix, late Director of the School of Mines at Ouro Preto, has fitly described the Province of Minas Geraes as having a "heart of gold in a breast of iron," and the simile only fails in its omission of reference to the wide range of mineral wealth which he himself has pointed out that it possesses.

Gold-bearing Formations.

Gold is found almost throughout the whole series of rocks in the gold-zone of Minas Geraes, but the bulk of that obtained by mining has been derived either from the quartz or jacotinga formations. The latter is a formation peculiar to Brazil which will be more especially alluded to later on. The quartz-formations have been extensively worked at Morro

Velho and Passagem, but with these exceptions no other property has been worked to any great depth or benefited by the use of modern machinery.

At Morro de Santa Anna, Rossa Grande, Pari, Antonia Pereira, and at many other points, operations have been conducted either by English or Brazilian companies, but in most cases under conditions which must have proved fatal to the success of almost any property.

The clay-formation has also been worked at several places with considerable success, notably at the Barra mine, situated near the village of Barra. This mine is the property of a Brazilian company and, as its name implies, the gold-bearing formation is mostly clay, yielding a steady and very remunerative return. It has been long and ably managed by Capt. Truran who works it entirely with native labour, and the rock requires most careful working to prevent accidents. The mineral is passed through Brazilian stamps driven by waterwheels. After stamping, the pulp is carried over blanket strakes and afterwards over tables having a good fall—a small quantity of water and a good fall being found to give the best results. The gold recovered is very fine and rarely visible in its matrix. The sand from the tables and blankets is washed by hand in bateas in the usual way.

With the exception of Passagem and Morro Velho the mineral has generally received the treatment described as used at the Barra mine, or in other words, a simple washing after stamping. It is reasonable to conclude that a very large amount of gold has been lost owing to the crude methods employed.

Method of Working.

The method of working has almost invariably consisted in following down a richly mineralized shoot in the lode, until water has been reached: then hand-power or, more rarely, that of water has been used to drain the excavation. Adits have been driven and shafts sunk; but anything in the nature of deadwork has been carefully avoided, and development regarded as a luxury too great to be indulged in. Small wooden pumps have generally marked the lowest level at which the Brazilian has cared to prosecute his search for the precious metal, and a portion of the free gold which the rock contained has satisfied him whether it would be worth his while to continue his work even above that horizon.

In most cases the mines were situated at points far distant from water-power and the mineral was carried on mule-back to the stream where water-power was available for crushing and treating the mineral; unless the ore was found sufficiently rich to bear this heavy cost the mine was abandoned.

The broken rock was often carried out of the mine by manual labour or at best wound by a mule or bullock-whim, and manual labour has been used even by some of the English companies for working the pumps.

The Brazilian stamps are almost entirely constructed of timber, having a wooden shaft with wrought-iron cams actuating iron tappets upon wooden stems. The shoes are of most excellent cast-iron made in the country, and the mortar boxes are of wood. If well constructed they may crush perhaps 15 cwts. per day, according to the nature of the rock; but it is more than doubtful whether the requisite degree of fineness is ever accurately determined. Where the ores crushed are pyritous, a heavy loss must occur by the simple method of gold extraction practised.

The Passagem mine, situated near to the old Portuguese city of Marianna, was formerly worked by the Anglo-Brazilian Gold Company, Limited, and at that time operations were conducted upon lines little better than those practised by the Brazilians. At present it is worked by the Ouro Preto Gold Mines of Brazil, Limited, and a very different state of things exists under the management of Mr. H. J. Gifford. The old incline-shafts have been enlarged and the mine developed upon modern principles. A rego of some miles in length brings an ample supply of water for power purposes and treatment of the ore. Hoisting and pumping, the latter a small item, is effected by water-power, which also drives a modern stamp-battery and a number of heads of Brazilian stamps.

The gold is rarely visible, and is mostly contained in pyrites, but the rock varies considerably. Specimens coated with asbestos have been taken from this mine. The treatment includes concentration upon blanket tables, pan-amalgamation, and a roasting and chlorination-plant. The latter was first most ably introduced and manufactured at the mine, and as it proved successful, a larger plant was sent out from England. The rock is trammed from the mine and then passes down chutes to the ore-bins, and from there to the rock-breakers and stamps. The whole operation is effected by gravitation and with a minimum of handling.

The Jacotinga Formation.

On account of its many peculiarities and the difficulty of working it, this formation possesses an interest apart from its being the only known example of gold occurring under such conditions. Roughly speaking it may be divided into two classes, the compact which requires stamping, and the soft which yields the bulk of the gold contained by the simple process of washing. These formations exist either separately or combined in a series of more or less parallel and irregular beds, striking

east-and-west with an underlie north or south of some 40 degs. They have been proved to be auriferous at various points for a distance of some 40 miles in a north-and-south direction, or at right angles to their strike.

The beds are not all auriferous, nor is any single one auriferous throughout its length; but shoots occur in groups at certain points parallel with the bedding and lying in its furrows. They dip irregularly towards the east about 30 degs., and contain gold unequally diffused throughout. In some shoots defined lines of gold or veins occur, which have been followed downwards at the Don Pedro mine for over 100 fathoms without any sign of their failing. Wherever the dip changes from a low to a high angle the shoots have become richer, and more or less they conform to the surface-contour.

The jacotinga is composed of micaceous iron ore, brown iron ore, saccharoid quartz, oxide of manganese, iron pyrites, iron glance, and clay, and in various shoots certain of these predominate or are absent, affording indications favourable or the reverse to the existence of gold.

At Morro d'Agoa Quente, Bananal, Brucutu, Pitangui, Sao Miguel, Itabira, Gongo Soco, Maquiné, and other points, English mining companies endeavoured in past years to work this formation with varying success. Of these companies the greatest and most successful were Gongo Soco and Maquiné, the former owned originally by the Imperial Brazilian Mining Association, the latter by the Don Pedro North d'El Rey Co., Limited. The only jacotinga mine now working is that at Maquiné.

At Gongo Soco, the lodes outcropped at the head of a valley, some 8 miles east of the town of Caethé. The dip of the auriferous shoots was easterly 8 to 30 degs., oblique to the normal direction and inclination of the beds. They were found to be very rich at this point, and were worked down to water-level, when the usual difficulties encountered made the owner willing, but not anxious, to sell. In 1825, the property passed into the hands of the English company, and from that date until 1856 mining operations upon an extensive scale were carried on. In 1832, the force employed by the company comprised 183 Europeans, 207 free Brazilians, and 404 slaves, the latter either owned or hired. During that year, 50,426 ounces troy of gold were obtained, 17,351·724 ounces being the result of stamping the compact jacotinga, and 33,074·988 ounces obtained by simply washing the soft variety.

Gold was found in this mine in extraordinary quantities at different times, and as much as 2,628 ounces were extracted in two days. A miner's hatcap-full taken out in January, 1829, upon being washed gave

331 ounces 14 dwts. of gold. Nuggets of over 240 ounces weight were met with, and in 1840 Capt. Blamey, assisted by two miners, extracted 1,260 ounces of gold in 3 hours.

The shoots dipped with the valley-line, and vertical shafts were sunk upon them at intervals; the deepest of these shafts was only 48 fathoms below adit. At this point difficulties were encountered, which led to the abandonment of the undertaking.

The treatment of the mineral was much the same as that to be described at the Don Pedro mine. The total amount of gold extracted from Gongo Soco mine between 1826 and 1856 amounted to 414,336 ounces troy.

The Don Pedro Mine.

The mine is distant about two miles north of the city of Marianna, and is situated in the "buraco" or "hollow" of Maquiné. The buraco occurs in a spur of the main range (see Figs. 1 and 2, Plate XIII.), and is partly the result of natural action and partly due to the removal of an immense quantity of material by the Antigos, who sluiced and open-cut very extensively here.

The capping of the spur, as also that of the main range, is an iron breccia, called canga. Under this lies a ferruginous sandstone, which forms the country rock, and enclosed in this are the beds of jacotinga, having an east-and-west strike, underlying about 40 degs. to 50 degs. north. In these beds occur the auriferous shoots before alluded to, dipping east into the spur.

Tradition assigns this place as the one where large quantities of gold had been extracted by one of the early Portuguese pioneers, who had taken a first instalment of his wealth home, and who died on his return journey without communicating the secret of the exact spot where he had made his find.

In 1865 a systematic search was undertaken by the Don Pedro North d'El Rey Co., which was then working the rock lodes of Morro de Santa Anna (another portion of their property), and they were rewarded by the re-discovery of the lost shoots. Great excitement followed the find, the rock mines were abandoned, and active operations were commenced at Maquiné. Adits were driven, and developments underground discovered shoots not known to exist at the surface, some branches being followed upwards, and pieces of gold taken out from under the grass roots.

The mine being at a considerable elevation, no difficulty was experienced with water, and gold was extracted in such quantities as enabled dividends of upwards of 100 per cent. per annum to be declared for three

years in succession, that is, 1867, 1868, and 1869. Deeper drainage then became necessary, and after several failures to drive adits through a belt of flucan which crossed the property, the existing adit, some 200 fathoms long, was completed. The water difficulty, however, was an increasing one, and though the pumping arrangements succeeded for some time, and allowed of a depth being attained of 50 fathoms on the incline, under adit, the machinery never had command of the water below the 30 fathoms level. Consequently, what with the breakdowns of expensive machinery, the re-opening of flooded workings in treacherous ground, and the difficulties attendant upon obtaining mineral under such adverse circumstances, the company had to suspend operations in 1880, and shortly afterwards the present company took over the property.

An interesting pamphlet, compiled from the official records of the company by Mr. John E. Dawson, contains fuller particulars of this mine than the scope of this paper will admit.

The present company has sunk an inclined shaft from the surface, 114 fathoms, and (to date) 59 fathoms below adit. The shaft is sunk in country rock, at an angle of 23 degs., and is 12 feet by 7 feet 6 inches within timbers. It is timbered throughout with the hardest and best timber procurable. The permanent sets are rarely under 20 inches through, and are spaced 6 feet apart, with intermediate sets between. Dividings, 10 inches by 6 inches, are placed under each cap, and the back and sides are close-lathed with candea poles. In some places where the ground sets off heavy on the timbers, rangers are carried under the caps, and the dividings are of iron. Double lines of tram rails of 28 inches gauge are laid in the whim end, and the engine end carries the column and pump-rods.

As in the formation itself, so in the country rock, great care is requisite in excavating the ground, which, often so hard as to require blasting, will in places run and bring excessive weight upon the timbers unless proper precautions are taken to avoid it. The sandstone is finely laminated, with intruding lines of jacotinga, which are always a source of danger.

This shaft had to be sunk diagonally under the old incline-shaft which crossed it between the 40 and 50 fathoms-levels, and over and under other levels, the work being successfully carried out without accident.

Cross-cuts are driven at intervals of 10 fathoms on the incline to the shoots. At present there are seven stopes carrying 9 feet caps with 9 feet legs, but these do not embrace the full width of the lode at this point, therefore stopes will be carried over these again until the whole formation is removed.

The system of stoping and timbering is shown in Fig. 3, Plate XIII., which shows a cross section of the stopes at the 50 fathoms horizon. The width of the lode has been proved at No. 4 stope by a rise to be 23 feet, but this does not represent its full width as the lode was still underfoot and water prevented any further test until such time as deeper drainage shall admit of its determination.

The workings have reached a point where the spur joins the main range, and it is here that predictions were made as far back as 1867 that the various shoots would unite into one main body of great richness. The shoots have formed the junction, and the rest of the forecast is being solved, so far with the most satisfactory results.

In the workings upon the formation the greatest care is required, and ordinary miners cause a series of runs which ruin the ground and are dangerous to life and the adjoining workings. The best men for this kind of work are natives trained from boyhood in the early operations of the company.

The back and side laths are of closely-fitted planks, tapered and driven together to prevent the slightest run, which must at once be stopped by ramming in "capim" (a kind of grass) at the back of them. Wet ends are kept closely breasted, and in driving, one breasting is heaved forth at a time and made secure.

The treacherous nature of the ground entirely disappears when the drainage of the formation is sufficiently deep, but for about 3 fathoms above water-level it continues saturated, and is, in its softer portions, almost unworkable, and decidedly so for profitable extraction.

The lines of gold have been referred to, but as they are one of the chief peculiarities of the jacotinga-formation further reference may not be out of place. They generally occur near to, but not in, the best looking jacotinga, and vary in value and size from a thread-like line to a rich "olha," or swell, jumping where a fissure occurs, sometime for many feet, but continuing in depth so far as yet attained.

The contortions of one of the auriferous shoots at the Maquiné mine is shown in Fig. 4, Plate XIII., and explains why an excavation 12 feet wide was required to remove the lodestuff. Fig. 5, Plate XIII., shows a cross section and the occurrence of another shoot, called the canoa or curve, from which large quantities of gold were extracted. The section also shows the position of the five lines of gold at that date.

To give some idea of the character of these lines the writer may mention his having seen about 5 cwts. of veinstuff taken out of one of them at the 45 fathoms horizon which yielded over 100 ounces of gold by

washing. Some of the prills were 3 inches to 4 inches long, and occurred as irregular slabs with sharp, jagged edges. A piece has been taken out of this mine 18 inches long, and on another occasion a bunch like seaweed, which fell to pieces on washing it. From pieces such as this the gold ranges down to the finest flour or float-gold, which, together with round shot-like pellets, require much care to prevent loss. The lines are carefully sealed with clay, marked by the mine captains with private marks, and guarded day and night till such time as the advance of the timbering permits of a further length being excavated. This is done in the presence of the head captain, who himself takes out the veinstuff and fills it into boxes, which are locked up by him and sent under guard to the reduction department. It should be mentioned that the various entrances to the mine are locked up at night, and all men are searched and have to change under inspection when lines are open in the mine. There has been both trouble and bloodshed in the past through gold-stealing, and life has been lost in consequence.

The mine is ventilated by means of an air-shaft parallel to and above the main shaft. From the bottom of the air-shaft wrought-iron air-pipes are led into the different workings, and an exhaust fan at the surface (driven off the main engine) keeps the mine as a rule well ventilated. In certain states of the atmosphere, however, the air is very dead, and what with the gases given off by the formation itself and the great masses of decaying timber in the mine, care has to be observed to avoid accidents

The mine being situated in a ravine sheltered from winds, but exposed to the full glare of a tropical sun, causes the question of ventilation to become occasionally inconveniently complicated and the temperature underground somewhat high.

The lowest parts of the mine remained under water from 1880 to 1890, when, the necessary machinery for draining it having been erected, the work of clearing out the old workings was commenced. These were found to have been filled up with the finest jacotinga carried in, and gradually deposited by the water until a mass had been formed, having the weight but not the stability even of the solid formation when wet. Great care had to be observed to avoid bursts of water, which, carrying with it the fine jacotinga, constantly threatened to fill the pumps up solid, and even with every caution would cut the buckets to pieces, sometimes after only half an hour's working.

The mine is now drained by means of a 5 feet Pelton waterwheel, situated upwards of 1,000 yards from the mouth of the shaft.

A line of 15 inches and 13½ inches diameter riveted steel pipes 1,530

feet long brings the water to the wheel under a head of 153 feet, and the power generated is transmitted by an endless wire-rope in two lengths to gearwork, situated near to the mouth of the shaft, which changes the rotary into a reciprocal motion. The speed of the transmission is upwards of 2,000 feet per minute, and the pulley-stands are of iron, four in number in the lower half and five in the upper half, carrying two sheaves 9 feet and 5 feet in diameter respectively, the upper sheave being 30 feet above the ground. The longest span in the transmission is 425 feet, and in this span the top or slack side of the rope is supported by an intermediate sheave. The gearwork actuates a line of rods working Cornish pumps with 15 inches plunger and 16 inches bucket lifts. The amount of incoming water is at present 26 cubic feet per minute.

The mineral is hauled to the surface by a mule whim, which is a slow and expensive method for over 100 fathoms of haulage; but a line of piping is laid and a second Pelton waterwheel will drive an air-compressor, the compressed air being led in pipes some 500 yards to an air-winding engine at the mouth of the shaft.

Until the new machinery can be completed for stamping, etc., the method of treating the ore will be that hitherto practised at this and other mines which have worked upon the jacotinga-formation. It is one capable of improvement, involves too much manual labour, not so much an object when slaves were employed, but important now that labour is free, scarce, and high priced.

Treatment of the Ore.

The ore is sent down to the reduction department either as "general" work or veinstuff, the latter oftener called "boxwork" on account of its being sent up out of the mine in locked boxes as before described.

The general work is trammed down an incline in cars controlled by a brake and tipped into the yard on the higher side of the reduction house, the boxwork being reserved for special treatment.

Separate wooden launders, carrying a stream of water regulated by stop-boards, run through the yard and discharge upon grizzleys and then upon flat copper gratings having slots $\frac{3}{8}$ inch by $\frac{1}{8}$ inch at the top end of each canoa. A woman is stationed at each launder to feed the ore into it regularly. Another native keeps each grizzley and grating clear of the "roughs," which are thrown aside for stamping. Prills of gold often come down in the general work and are picked off the gratings, a small reward being given to the native for each prill found. The sand which passes through the grating is carried by the water over an inclined table provided with riffles which catch the heavier gold.

From this table it falls into the head of a canoa or kind of long-tom having its narrow end lowest. The lower end is provided with stop-boards, which are gradually raised by another native who slowly rakes the rough sand as it accumulates, back against the water to the head of the canoa. A rich concentrate results, which is cropped from the head of the canoa for separate treatment with the boxwork.

The sand carried over the stop-boards at the lower end of the canoa then flows over blanket-strakes covered with a rough baize, the fine sand escaping and the rough being reserved for the stamps. The blankets are taken up at intervals by women who attend to them and these blankets are washed in a tank, the lowest being removed and replaced first. This sand is passed through a special canoa reserved for the veinstuff and croppings of the other canoas. Extra care is given to the rich mineral passed through this canoa which is slightly different in construction from the others, being smaller and having basket sieves of fine mesh. These can be lifted out for examination and the prills picked out. Small quantities only are passed and the whole operation is closely watched by the reduction officer to prevent theft.

The highly concentrated sand from the small canoa is washed by hand in bateas and the gold, almost clean, is put into a locked "taxo."

The tailings from the small canoa are caught and passed through the larger canoas with the general work so as to ensure, so far as the process will allow, a complete saving of the gold.

Jiggers were at one time employed, but their success was not sufficiently proved to warrant a further trial of them and the same may be said of buddles.

Great skill is shown by the expert user of the batea, and a single visible particle of gold will be shown up if placed as a test in a wash of dirt. Women are employed for this work in the reduction-house, and they use the batea with a circular sweep and side shake which brings the gold first to the centre and afterwards to the side of the batea as the waste is gradually washed away. To prevent the float-gold from escaping, the juice of a pounded herb is sprinkled upon the water in the batea when cleaning the gold.

A table is appended containing particulars of the amount of gold recovered and the percentage of loss by assay for several years. The loss, some 35 per cent., seemed excessive for free gold, and the writer sought a remedy in a finer crushing of the sand than had hitherto been adopted. The results obtained after five separate crushings and washings showed that gold of the utmost degree of fineness remained enclosed in the

extremely fine sand of the fourth crushing. Further attention to this matter will be given when the work now in hand permits of its being dealt with.

It will be seen from the table that the amount of gold extracted from the Don Pedro mine during the period from 1865 to 1892 amounted to 158,127 ounces troy, but it should be noted that mining operations were much retarded prior to 1880, in which year they stopped, and that even now they have not been fully resumed.

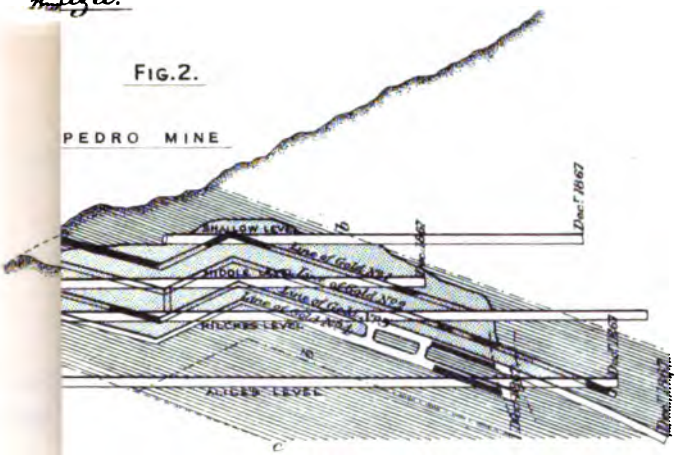
In concluding this paper, the writer would venture to suggest that the interest which attaches to gold-mining in Brazil is not so much due to what has been done, as to the possibilities of the country as a field for future work. Regarded in this light, it will be found of much greater interest and importance than the record of what has been, up to the present, a mere surface-scratching of a huge territory.

Year	Weight Treated.		Gold Extracted.		Yield per Ton.			Loss by Assay of Waste	Workmen Employed		Working Costs			Profit			Loss		
	General.	Veinstuff.	General.	Veinstuff.	General.	Veinstuff.	Average.		European.	Native.	£	s.	d.	£	s.	d.	£	s.	d.
	Tons.	Tons.	Oitavas.	Oitavas.	Oitavas.	Oitavas.	Oitavas.	Per Cent.	No.	No.									
1865	[illegible]	...	14,249·5	...	...	...	4·35	...	...										
1866	[illegible]	...	7[illegible],348	...	...	...	5·50	...	...		3[illegible],911	0	0	10,040	0	0			
1867	[illegible]	...	1[illegible]2,397	...	...	...	8·91	...	23	345	36,147	19	8	[illegible]	0	0	...		
1868	[illegible]	103·35	169,291	35,264	6·80	341·10	8·21	...	26	3[illegible]3	37,304	0	0	60,[illegible]8	0	0			
1869	[illegible]	81·60	168,253	32,114	6·60	393·55	7·84	...	33	418	3[illegible],[illegible]0	0	0	60,438	0	0			
1870	[illegible]	39·00	74,355	13,743	2·82	365·20	3·33	...	42	426	37,[illegible]2	0	0	42	0	0			
1871	[illegible]	144·90	95,564	26,331	4·01	112·69	5·08	...	39	3[illegible]9	41,954	0	0	8,606	0	0			
1872	[illegible]	51·76	71,325	10,829	2·57	209·21	2·96	42·18	44	445	41,119	0	0				6,137	0	0
1873	[illegible]	14·19	58,109	6,170	1·908	434·81	2·144	35·00	46	427	40,207	0	0				8,316	0	0
1874	[illegible]	44·60	57,244	10,837	2·051	220·56	2·507	20·77	37	321	32,706	8	0				4,464	0	0
1875	24,583	...	7,830·2	...	3·18	...	3·18	...	...	...	31,704	0	0	8,380	0	0			
1876	14,402	3·44	45,982	1,697	3·08	...	3·30	...	26	238	24,892	7	8				2,034	10	8
1877	22,686	...	51,601	35	2·30	...	2·30	...	26	290	28,366	11	8	...			4,004	0	0
1878	23,549	...	33,878	...	1·41	...	1·41	...	23	167	27,091	1	11				8,084	13	10
1879	19,031	...	10,588	...	0·55	...	0·55	...	20	152				...			10,[illegible]8	0	0
1880	4,739	...	10,560	...	2·22	...	2·22	...	...	...				...			8,885	0	0
1881	884	...	2,320	...	2·62	...	2·62	...	...	...	6,571	19	11	...			8,140	0	0
1882	...	...	...	...	...	...	...	...	...	...	...			...					
1883	...	...	...	...	...	...	...	...	...	...	...			...					
1884	...	...	2,861	...	...	...	...	...	...	...	...			...			...		
1885	...	...	3,614	...	...	...	...	...	...	...	...			...					
1886	...	...	1,681	...	...	...	...	...	...	...	...			...					
1887	...	...	...	...	...	...	...	...	...	...	...			...			...		
1888	...	...	5,934	...	...	...	...	...	...	...	...			...					
1889	...	...	2,220	...	...	...	...	...	74		...			...					
1890	...	...	509	...	...	...	...	...	110		...			...			...		
1891	...	...	4,434	...	...	...	...	...	145		...			...			...		
1892	...	...	20,815	...	...	...	...	...											

REMARKS.—1865, Boxes containing 96 lbs. of veinstuff, yielded upwards of 60 oitavas of gold. 1866, Line discovered yielding 670 oitavas per ton. 1867, One nugget extracted measured 18 in. by 3 in., and weighed 48 ounces; veinstuff extracted yielding 1,500 oitavas per ton. 1869, Water difficulty commenced. 1870, Difficulty continued; erection of heavy machinery commenced. 1871, Erection of heavy machinery continued. 1872, Erection of heavy machinery continued; lower levels under water. 1873, Erection of machinery continued; lower levels under water. 1874, Erection of machinery suspended. 1875, Erection of machinery suspended. 1876, Erection of machinery resumed. 1877, Erection of machinery resumed. 1878, Erection of machinery completed, but fails. 1879, Bottom of mine under water. 1880, Additional machinery erected. 1881, Failure of machinery; suspension of operations. 1883, Property passed into hands of Don Pedro Gold-Mining Co. 1884, Sinking of new shaft commenced. 1885, Sinking of new shaft continued. 1886, Sinking of new shaft continued. 1887, Mine drained to 40 fathoms level. 1888, Appliances fail to deal with accumulated water. 1890, New machinery erected and mine drained; and re-opening bottom of mine. 1891, Sinking new shaft to 50 fathoms level. 1892, Sinking new shaft to 60 fathoms level.

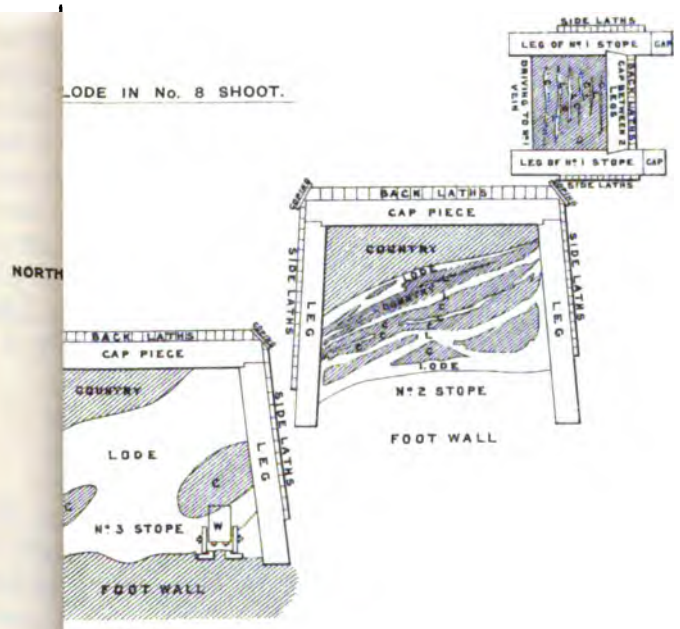
FIG. 2.

PEDRO MINE



200 Feet to 1 Inch.

LODE IN No. 8 SHOOT.



et to 1 Inch.

CROSS SECTION OF THE LODE
AT THE
DON PEDRO MINE,
AT A RIGHT ANGLE WITH THE DIP.

REFERENCES

Dark Auriferous Jacotinga or Lode

Auriferous Lody Matter

Lines of Gold Nos 1, 2, 3, 4, & 5.

Year.	Weight Treated.		Gold Extracted.		Yield per Ton.			Loss by Assay of Waste.	Workmen Employed		Working Costs.	Profit.	Loss.
	General.	Veinstuff.	General.	Veinstuff.	General.	Veinstuff.	Average.		European.	Native.			
	Tons.	Tons.	Oitavas.	Oitavas.	Oitavas	Oitavas.	Oitavas.	Per Cent.	No.	No.	£ s. d.	£ s. d.	£ s. d.
1865	3,437·8	...	14,949·5	...	...	...	4·35	...	...	...	...	...	...
1866	12,779	...	70,348	...	...	...	5·50	...	...	...	27,211 0 0	10,040 0 0	...
1867	20,453	...	182,397	...	...	...	8·91	...	23	345	26,137 19 8	54,572 0 0	...
1868	24,794·65	103·35	169,291	35,264	6·80	341·10	8·21	...	26	373	27,564 0 0	60,573 0 0	...
1869	25,472·40	81·60	168,253	32,114	6·60	393·55	7·84	...	33	418	32,370 0 0	55,428 0 0	...
1870	26,362·00	39·00	74,355	13,743	2·82	365·20	3·33	...	42	426	37,572 0 0	42 0 0	...
1871	23,825·10	144·90	95,564	26,331	4·01	112·69	5·08	...	39	379	41,954 0 0	8,606 0 0	...
1872	27,623·24	51·76	71,325	10,829	2·57	209·21	2·96	42·18	44	445	41,119 0 0	...	6,027 0 0
1873	30,448·50	14·19	58,109	6,170	1·908	434·81	2·144	35·00	46	427	40,297 0 0	...	8,316 0 0
1874	27,908	44·60	57,244	10,837	2·051	220·56	2·507	20·77	37	321	32,706 8 0	...	4,354 0 0
1875	24,583	...	7,830·2	...	3·18	...	3·18	...	...	...	31,703 0 0	3,280 0 0	...
1876	14,402	3·44	45,982	1,697	3·08	...	3·30	...	26	238	24,892 7 3	...	2,021 10 5
1877	22,686	...	51,601	35	2·30	...	2·30	...	26	290	28,366 11 8	...	4,994 0 0
1878	23,549	...	33,878	...	1·41	...	1·41	...	23	167	27,091 1 11	...	8,984 13 10
1879	19,031	...	10,588	...	0·55	...	0·55	...	20	152	...	...	19,759 0 0
1880	4,739	...	10,560	...	2·22	...	2·22	...	...	...	...	...	8,388 0 0
1881	884	...	2,320	...	2·62	...	2·62	...	...	...	6,571 19 11	...	8,749 0 0
1882	...	...	...	...	...	...	...	...	...	...	...	...	...
1883	...	...	...	...	...	...	...	...	...	...	...	...	...
1884	...	...	2,861	...	...	...	...	...	...	...	..	...	...
1885	...	...	3,614	...	...	...	...	...	...	...	...	...	...
1886	...	...	1,681	...	...	...	...	...	...	...	...	...	...
1887	...	...	...	...	...	...	...	...	...	...	...	...	...
1888	...	...	5,934	...	...	...	...	...	...	...	...	...	...
1889	...	...	2,220	...	...	...	...	...			...	...	...
1890	...	...	509	...	...	...	...	...	74		...	...	...
1891	...	...	4,434	...	...	...	...	...	110		...	...	...
1892	...	...	20,815	...	...	...	...	...	145		...	...	...

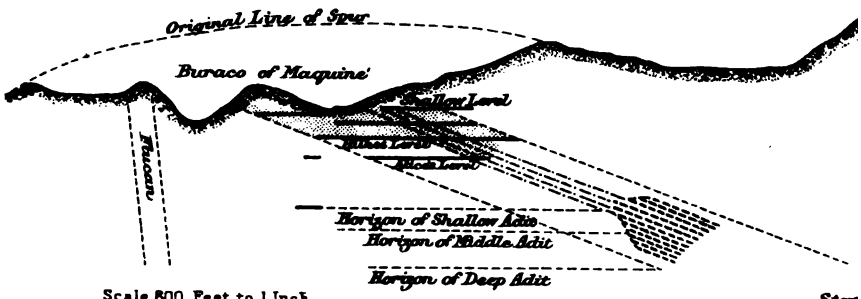
REMARKS.—1865, Boxes containing 96 lbs. of veinstuff, yielded upwards of 60 oitavas of gold. 1866, Line discovered yielding 670 oitavas per ton. 1867, One nugget extracted measured 13 in. by 3 in., and weighed 48 ounces; veinstuff extracted yielding 1,500 oitavas per ton. 1869, Water difficulty commenced. 1870, Difficulty continued; erection of heavy machinery commenced. 1871, Erection of heavy machinery continued. 1872, Erection of heavy machinery continued; lower levels under water. 1873, Erection of machinery continued; lower levels under water. 1874, Erection of machinery suspended. 1875, Erection of machinery suspended. 1876, Erection of machinery resumed. 1877, Erection of machinery resumed. 1878, Erection of machinery completed, but fails. 1879, Bottom of mine under water. 1880, Additional machinery erected. 1881, Failure of machinery; suspension of operations. 1883, Property passed into hands of Don Pedro Gold-Mining Co. 1884, Sinking of new shaft commenced. 1885, Sinking of new shaft continued. 1886, Sinking of new shaft continued. 1887, Mine drained to 40 fathoms level. 1888, Appliances fail to deal with accumulated water. 1890, New machinery erected and mine drained; and re-opening bottom of mine. 1891, Sinking new shaft to 50 fathoms level. 1892, Sinking new shaft to 60 fathoms level.

Federated Institution of Mining Engineers.
Transactions 1892-93.

To illustrate Mr. E. M. Tous

FIG. 1.

LONGITUDINAL SECTION THROUGH THE THIRD BED OF JACOTINGA



Scale 800 Feet to 1 Inch.

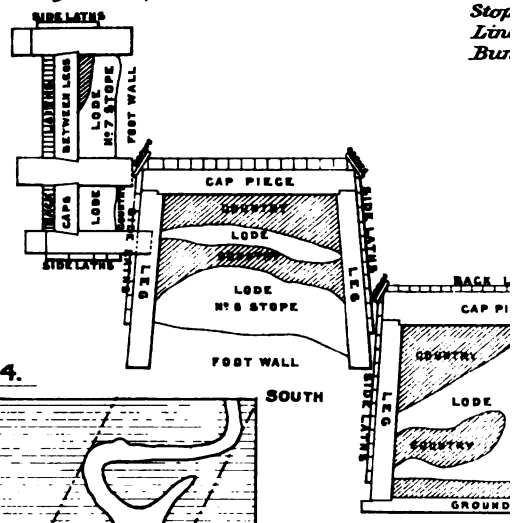
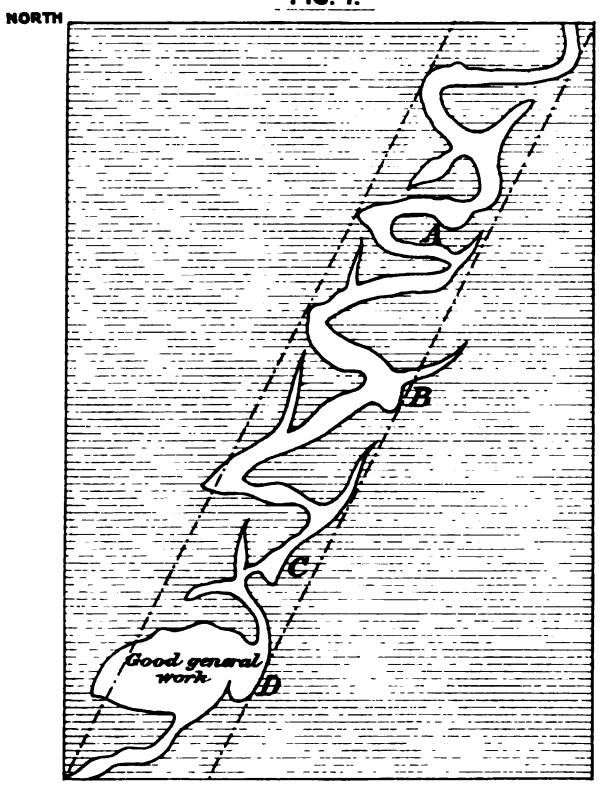


FIG. 4.



REFERENCES

A First Line of Gold
B Second ___ do ___
C Third ___ do ___
D Fourth ___ do ___

Scale 16 Feet to 1 Inch.

North of England Institute of Mining & Mechanical Engineers

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.

By A. G. CHARLETON.

Part I.—Introduction.

The title of this paper has been suggested to the writer by a most interesting contribution on the subject of gold-quartz reduction, read by Mr. A. H. Curtis, at a recent meeting of the Institution of Civil Engineers, which the writer in common with other visitors, had the pleasure of hearing discussed at the two following sessions.

The subject is of such wide scope, that the writer ventures to think some of the points Mr. Curtis dealt with may be enlarged upon, and in fact the subject can be approached from several different points of view (notably from a metallurgical one) without exhausting it, or in any way attempting to trench on matters which Mr. Curtis has more particularly disposed of.

In summing up, Mr. Curtis arrives at certain general conclusions, which are almost entirely in accordance with the writer's own experience, viz.:—

I.—That the most suitable machines for the preliminary coarse-crushing of nearly all ores, (depending on individual circumstances, referred to later on) come under one of the two following classes :—

A. Those with a reciprocating-jaw action, either hung at the top on a rocker shaft, so as to swing freely backwards and forwards at the bottom (on the well-known Blake and Marsden principles), or pivoted at the lower end, so as to move to the greatest extent at the top (like the Dodge).

B. Those with a gyratory movement (like the Gates or Comet crusher).

II.—That, for medium-coarse (below 2½ inches) to fine-crushing, necessary for an ore which has to be amalgamated, concentrated, lixiviated, chlorinated, or treated by any of the various modifications of these processes which have sprung up of late years (each with some special claims of its own), the types in their own particular provinces, of the best classes of machinery to employ, are represented by :—

C. Gravitation stamps.

D. First-motion rolls for medium and fine work ; or geared-rolls for coarser ore sizes, and

E. Centrifugal roller-mills (such as the Huntington) which have stood the test of wide use, and time.

If, however, it is intended to reduce to pulp ore already crushed fine, as required in certain branches of amalgamation, one must add to this list:—

F. Edge-roller-mills of the improved Chilian type, Frankfort mills; and what are known in America as

G. Combination-pans, a modified form of the old Wheeler-pan.

Coarse-crushing.

Although hand-spalling with a sledge still holds its own for breaking gold-quartz in a number of Queensland mills and other places where stereotyped prejudice still holds it in position, mechanical means should generally be used for breaking the ore (as it comes from the mine) to a convenient size for its subsequent treatment. The exceptions to this rule are: If the stone contains mineral, which can be picked out at once and shipped to smelting-works to be otherwise dealt with; if manual labour be exceptionally efficient and cheap; if power of any sort be exceptionally dear; if the location of the mine* render the transport and operation of heavy machinery practically out of the question; or if the location of an existing mill of old construction will not allow of the introduction of an ore-breaker with its accompanying bins, grizzleys and automatic-feeders, etc. In point of fact the first is the only case in which spalling can compete with rock-breakers in a modern mill properly located and arranged,† as for instance, where a concentrating ore carries some such combination as argentiferous galena and zinc blende, mixed with carbonate of lead, and copper pyrites or iron pyrites, spathic iron and quartz. The result of crushing ore like this, would be to break up much of the blende, pyrites, etc., into grains, which, with specific gravity ranging only from 3·9 to 5·1, could not be thoroughly separated from one another by jigging, or any other mechanical dressing process. A mixture of these minerals‡ has no market, and hence crushing without some previous selection would obviously result in loss.

The ore for example at Ems which is divided into (1) rich galena ore; (2) cobbing ore; (3) pyritiferous cobbing ore; and (4) barren rock furnishes an illustration given by Kunhardt.§

In many localities, however, as he remarks, loss or no loss, the value of labour is too high to admit of spalling and cobbing being carried out together (as they have to be in such cases) and at best it is a pain-

* Since the introduction of sectionalized machinery and the application of electricity to long-distance transmission, remoteness from civilization influences this aspect of the question, more than local engineering obstacles.

† Assuming it to have a capacity of 20 tons a day, or anything over that amount.

‡ Above certain proportions small enough to be neglected.

§ *School of Mines Quarterly*, series 2. "The Art of Ore Dressing in Europe."

fully primitive practice, which, carried out on a large scale, retards or even prevents, by the sedentary nature of the work, a healthy physical development of the youth of the mining population, though on the other hand, it certainly tends to stimulate their faculties of observation.

In class A, the best-known crushers are the Blake and Blake-Marsden stone-breakers.

The Blake-Marsden hand-hammer-action crusher takes, it is claimed, less power to get through a given amount of work than the Blake; nevertheless it does not appear to have come into such general favour for mining purposes. Perhaps this may be accounted for by its greater prime cost, weight, and the large space it occupies, for it seems a simple and well-built machine.

The chief disadvantages, which attach to the use of the above class of ore-breakers, are:—

(*a*) That the moving jaw only does effective work during the forward stroke, rendering the action an intermittent one.

(*b*) That thin, flat pieces of rock may at times pass the jaws without being broken, an objection, it may be remarked, which is not of very great consequence to the miner, unless the product of the machine is unusually large, and goes direct to automatic feeders.

(*c*) That the stone leaving the machines is of continually varying sizes.

With regard to the Dodge, its special advantages are:—

(*a*) Its light weight.

(*b*) The jaw being fixed at the bottom, (1) the size of the product can be more easily regulated; (2) is more uniform in size; and (3) the stone can be crushed down finer than with crushers of the preceding class.

The Dodge is more particularly recommended on these grounds, for fine-crushing in concentration-works, although its capacity is more or less limited as compared with the Blake, owing to the fact that it gives a finer product.

It should also meet a want in small mills, which cannot keep a more powerful breaker fully employed, or as a preparatory machine for finer crushing, in Rolls or a Huntington.

Belonging to class B there are:—

1. *The Gates or Comet Rock and Ore-breaker.*—Owing to the gyratory movement of the breaking-head of this machine on an eccentric, within a circular outer shell, which is protected with toothed liners, and is shaped like an inverted cone, it is claimed:—

(*a*) That flat pieces of rock cannot pass through it uncrushed to the same extent, as in a machine with reciprocating-jaws.

(*b*) That as the area of breaking-surface increases towards the discharge end, the material as it is broken smaller is spread over a larger space, which results in finer crushing than is practicable with a reciprocating jaw-machine.

(*c*) That as the head is loose on the eccentric spindle, there is no grinding action, and there is a line of crushing-surface from top to bottom of the head and liners in constant action.

(*d*) The area of breaking-surface is about three times as great as in reciprocating machines of similar power. This seems to admit of the machine doing nearly treble the work in any given time, driven at the same speed, and of tipping into it large quantities of stone (using a hopper); dispensing with much of the attention necessary with machines belonging to class A.

(*e*) That, having a comparatively small crushing-surface acting continuously, dispensing with a fly-wheel to store up power (part of which is wasted), and the rock which is to be broken being supported at its ends only, in the circular crushing-chamber, less power is required, as compared with a jaw machine, to do a given amount of work.

Quoting the report of a committee, on a competitive trial between a 9 inches by 15 inches Blake-Marsden, and a 9 inches by 14 inches Gates, at Meriden, Connecticut, on May 30th, 1883, the makers of the Gates assert that, crushing the same kind of stone to an equal size, the latter machine crushed over three times as much in a given time, and showed a saving of about 33 per cent. of the indicated power consumed in doing the work.

On the other side, it must be said, that a Gates of an equal capacity will not take in a lump of rock of as large sectional dimensions as a Blake or Marsden; and the latter machines have the advantage in respect of weight and prime cost; the price of the large sizes is in fact extremely heavy, and the height of the Gates is also a disadvantage, where fall has to be economized. The injury done to the machine, which might result from a hammer head, or drill falling into it (a not unfrequent occurrence through carelessness, or occasionally other reasons) has also to be considered, and there is no doubt that the Gates requires particular attention, in keeping it properly lubricated with suitable lard, or heavy lubricating oil. The head and liners are made of specially chilled, cast white-iron.

There is one particular case, however, which should be pointed out, in which the Gates seems to possess very special advantages over other crushers, and that is, where there is a wide lode yielding large quantities

of milling ore, in which the stone breaks "large" in stoping it down, and requires in consequence to be spalled, to get it into the jaws of an ordinary breaker. Under such circumstances, a Gates may obviously serve a very useful purpose indeed, as the larger sizes will take in whole lumps, as big as can be handled, and by this means the tedious and expensive process of breaking in the mine, or "breaker-floor," is avoided.

The measure of economy in using a large sized breaker of the kind will necessarily depend, however, on being able to keep it fully employed, as well as possessing ample storage-bin room and driving power. As an instance of the work it can accomplish under such circumstances, the Caledonia mill in Dakota may be quoted,* where one No. 6 Gates, with receiving-openings 12 inches by 18 inches, attended by one man, crushed 200 tons in 10 hours, and did the work formerly set for three No. 5 Blakes (the largest ordinary pattern in the market), with a receiving-opening 9 inches by 15 inches. These latter took five men 20 hours, it is said, to produce the same result, requiring the same amount of power. It is asserted by the makers of the Gates, that its action entails less stress on the structure it is mounted upon, than is the case with a reciprocating breaker, but one is somewhat inclined to doubt whether this holds good in starting it when empty, whatever may be the case whilst it is running full.

Its size, and weight, must evidently be special objections, when it has to be mounted on a lofty structure (like the back floor of a stamp mill); and where the stone is divided, along a long line of bins, the advantage of using one large machine, is more or less offset by the difficulty of distributing the ore between them, unless there is an exceptionally large fall to spare. Under such circumstances the only practical escape from the difficulty, is to set the breaker apart from the mill (if possible close to the shaft); and it is not improbable that this is, as a rule, (where the mine and mill are owned by the same company, and the former keeps the latter entirely occupied), the best disposition to adopt. This does away with much of the dust, which plays havoc with the bearings of the other machinery of the mill, permits of lighter framing for foundations and superstructure, less grading (in some cases),† and a smaller annexe to the main building.

2.—*The Lowry Ore-breaker.*—A second form of gyratory crusher has quite recently been introduced by the National Machinery Co., of Tiffin, Ohio.

* "Gold-milling in the Black Hills," by H. O. Hofman. *Trans. Am. Inst. Min. E.*, vol. xvii., page 498.

† When rock-breakers and ore-bins are used with automatic-feeders at the back of a stamp-battery, which has tables and concentrators below it, the least practicable fall that ensures the automatic movement of the ore through the various stages of the process is about 33 feet from the rock-breaker to the concentrator floor.

A description of this crusher appeared in the *New York Mining Journal* of December 5th, 1891.

Its construction is illustrated by a diagram, which shows it in section, with a removable revolving top for fine-crushing, containing two or more holes, to regulate and spread the stone round the breaker-head. The ore is thrown into a hopper, and is discharged as fast as it is broken, avoiding any danger of clogging. The Lowry ore-breaker appears to occupy the same position with regard to the Gates, that the Dodge does to the Blake, as the vertical shaft is fulcrumed below the crusher-head instead of above it; consequently there is less motion, so it is asserted, at the bottom of the jaw, and the product is said to be more even than that of any of the jaw-crushers, in which the jaw is pivoted at the top, a statement which is no doubt correct.

The chilled-iron head or cone appears smaller in the Lowry breaker than in the Gates. The chilled-iron ring or liner, which forms the outer crushing-face is cast in one solid piece, having a solid turned bearing and supporting-backing behind it. The machine is adjusted for crushing to various sizes by screws at the side of the crushing mortar, by which the liner can be raised or lowered. This is done to obviate the necessity of lifting the vertical shaft, carrying the crusher-head, the bottom of which always remains in the oil chamber of the eccentric, at the base of the machine. The vertical shaft is driven by ropes with sufficient laps round the pulleys, and with provision for adjustment in the tension-pulley.

As one of the chief advantages of this machine, the manufacturers claim that the crusher-head strikes downward, and has a tendency to draw in the material to be crushed, which would not be the case if the vertical shaft were fulcrumed at the top.

These breakers are made in nine sizes, having a capacity varying between 5 and 250 tons per hour.

Without having seen both machines at work and knowing more about the Lowry, it is impossible to institute a fair comparison between it and the Gates. But it is probable that, comparing the former with reciprocating-jaw machines, most of the arguments for and against the Gates seem to apply equally to its new competitor.

The purpose for which an ore-breaker is intended, its capacity, saving in space occupied, weight, quickness in setting to work, ease of repair, simplicity of construction, wear per ton of ore, liability to serious or minor accidents, first cost, and consumption of labour in attendance, lubricants, and power required per ton of ore crushed, will all influence the choice of a machine, and no hard-and-fast line can be drawn, between the

various coarse-crushers which have been mentioned, each possessing a sphere of usefulness of its own. In fact, as some of the above conditions are to a certain extent conflicting, a careful consideration of the particular circumstances of each case is absolutely necessary. In judging of the relative economy of different crushers in regard to consumption of power, it is perfectly correct that the only true test of their efficiency is the actual, indicated, useful effect shown per lb. of fuel burnt in cubing a certain class of stone to a given size. This method of comparison is, not however, so entirely reliable as would at first sight appear, unless the machines under trial be driven with the same engines and boilers, by the same enginemen.

The consumption of fuel will, in fact, differ in different works, according to its quality or description, the size and type of engine and boiler employed, and the care bestowed in looking after them.

Further than this, it is absolutely necessary to compare the exact time the crushing lasted, deducting all stoppages, since an engine which is idle, during the time the boiler fire is alight, may be consuming—in proportion to the useful work done—much more fuel than either the indicated or real horse-power (measured while the engine was working) would lead one to suppose. The different sizes, weights, capacities, size to which the stone is cubed, size and speed of driving-pulleys, nominal horse-power expended, and cost of the Blake, Blake-Marsden, Dodge, Gates, and Lowry ore-crushers, are given in the subjoined tables, as far as it is possible to ascertain them.

DIMENSIONS, PRICES, AND PRODUCT OF THE BLAKE STONE- AND ORE-BREAKER.*

No.†	Size of Receiving Opening.	Approximate Product per Hour in Tons crushed to 2 inch size	Weight of Heaviest Piece.	Total Weight.	Extreme Dimensions.						Driving Pulley.				Proper Speed. Revs. per Min.	H.P. Required.	Price F.O.B. Chicago.		
					Length.		Breadth.		Height.		Diam.		Face.						
	Inches.		Lbs.	Lbs.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.			£	s.	d.
...	3 × 1½	Laboratory	40	100	1	1	0	6	0	10	0	5	0	1	300	...	10	8	4
A	10 × 4	4	1,993	4,719	4	6	4	0	3	11	1	8	0	6	...	4	62	10	0
2	10 × 7	6¾	3,950	7,896	5	4	4	6	4	5	2	0	0	7½	275	7	104	3	4
5	15 × 9	10¾	7,179	15,749	6	8	5	0	5	3	2	6	0	9	...	10	156	5	0
8	20 × 10	13½	7,700	17,000	6	10	5	9	5	11	3	0	1	0	250	14	218	15	0

* Messrs. Fraser and Chalmers' *Catalogue, No. 4* (Gold and Silver Mills), and Egleston's *Silver*, page 358.

† There are various intermediate sizes not mentioned in the table; the 20 inches by 15 inches, with a product of 20 tons per hour, being the largest.

Size A—Takes pieces 4 inches thick, and crushes to ½ inch or less. 2—Takes pieces 7 inches thick, and crushes to ¾ inch or less. 3 and 4 are used for road-ballast, furnaces, and breaking smaller for other crushers. Mr. H. S. Munroe* places the cost of repairs for eight 7 inches by 15 inches lever-pattern crushers (Blakes) with corrugated jaws, estimated to have crushed 224,203 tons of limestone, at Bonne Terre, Missouri, in 12 months, at:—

	£	s.	d.
12 levers, at $25·00	62	10	0
9 jaw-plates, at $15·00	29	1	3
12 jaw-plates, at $12·00	30	0	0
Toggles, check-plates, and sundries ...	51	12	6
Total cost	£173	3	9

This represents an average of about £20 16s. 8d. for each crusher, breaking 80 tons per diem, to 1½ inches, but does not include the cost of babbitting bearings, or labour in making repairs.

From these data, the average life of the wearing parts of a jaw-crusher, appears (similarly circumstanced) to be about 8 months.

The lower box of the pitman-shaft must be packed with thin wood packing, to prevent the key tightening the box to the shaft. Iron plugs should be kept in the oil-holes, and if the fixed jaw requires to be cast-up, it should be backed with zinc plate about ¼ inch thick.

The amount of product depends on the distance the jaws are set apart, the speed, and also on the nature of the ore.

The product given in the table assumes the jaws set 1½ inches open at the bottom, the machine run at proper speed, and properly fed, but it will vary somewhat with the character of the stone, brittle stone for instance going through faster than sandstone.

The No. 2 Blake is made in sections for mountain transport. Total weight, 6,881 lbs.; cost, £145 16s. 8d. No piece of this machine weighs over 332 lbs.

DIMENSIONS, PRICES, AND PRODUCT OF THE DODGE CRUSHER.†

No.	Size of Jaw Opening.	Approximate Product per Hour to Nut Size.	Total Weight.	Driving Pulley. Diameter.	Width of Belt used.	Proper Speed. Revolutions per Minute.	H.P. Required.	Price F.O.B. Chicago, Complete.		
	Inches.	Tons.	Lbs.	Inches.	Inches.			£	s.	d.
1	4 × 6	½—1	1,200	20	4	275	2—4	52	1	8
2	7 × 9	1—3	4,300	24	5	235	4—8	93	15	0
3	8 × 12	2—5	5,600	30	6	220	8—12	114	11	8
4	10 × 16	5—8	12,000	36	8	200	12—18	187	10	0

* "The New Dressing Works of the St. Joseph Lead Company." *Trans. Am. Inst. Min. E.*, vol. xvii., page 659.

† Messrs. Fraser and Chalmers' *Catalogue, No. 4.*

DIMENSIONS, PRICES, AND PRODUCT OF THE BLAKE-MARSDEN (WITH LEVER AND ECCENTRIC MOTION) STONE-BREAKERS.*

Size of Receiving Opening.	Approximate Product per Hour to Road Metal Size, 2½ Inches.	Total Weight of Machine.	Extreme Dimensions. Length.	Breadth.	Height.	Driving Pulley. Diam.	Face.	Proper Speed. Revolutions per Minute.	H.P. Required.	Price.
Inches.	Tons. Cwts.	Lbs.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.			£
12 × 8	5 8	10,080	8 1	3 7	4 9½	2 0	0 5	250 to 300 revolutions.	5	113
15 × 8	6 5	12,880	8 9½	4 10	5 3	2 6	0 6		7	135
15 × 10	7 10	15,680	8 9½	4 10	5 3	2 6	0 7		8	150
18 × 9	8 15	17,584	8 11	4 11	5 0½	3 0	0 7		9	165
20 × 10	10 0	22,400	9 11	5 5	5 4½	3 0	0 7		10	180
24 × 13	15 0	30,240	10 6½	5 8½	6 7½	3 0	0 9		12	263
24 × 16	16 0	31,360	10 6½	5 8½	6 7½	3 0	0 9		14	275
24 × 17	16 5	31,920	10 6½	5 8½	6 7½	3 0	0 9		14	282
30 × 18	20 6	33,600	...	...	...	...	...		18	375
34 × 18	23 2	42,560	...	...	...	...	...		20	413

The makers state that it is advisable to use an engine of 2 horse-power more than stated in the table, as it is more economical to run a larger engine, than to run one up to its full power (this remark also applies to the Blake and the Gates crushers). The principal working parts are all crucible steel.

DIMENSIONS, PRICES, AND PRODUCT OF THE GATES OR COMET ORE-CRUSHER.

Size.	Dimensions of the Three Receiving Openings combined.	Dimensions of each Receiving Opening, about.	Weight of Breaker.	Capacity per Hour in Tons of 2,000 Lbs. passing 2½ inches Ring according to Character of Ore.	Dimensions of Driving Pulley. Diam.	Face.	Space occupied by Breaker set up. Height from Bottom Frame to Top of Hopper	Width of Frame.	Length of Frame.	Diameter of Hopper.	Revolutions of Pulley.	H.P. of Engine recommended to drive Breaker, Elevator, and Screen. Limestone.	Granite.	Net Price F.O.B. London.
	Inches.	Inches.	Lbs.		In.	In.	In.	In.	In.	In.				£
00	2 × 12	2 × 4	500	Laboratory and sampling	8	2½	24	17	26	13	700	½	½	25
0	4 × 30	4 × 10	3,100	2—4	16	6	48	30	73	28	500	4	4	85
1	5 × 36	5 × 12	5,500	4—8	20	7	54	31	76	37½	475	8	8	125
2	6 × 42	6 × 14	7,800	6—12	24	8	60	39	90	39½	450	12	15	165
3	7 × 45	7 × 15	13,500	10—20	28	10	73	48	103	44½	425	20	30	250
4	8 × 54	8 × 18	20,000	15—30	32	12	85	54	114	51	400	30	40	400
5	10 × 60	10 × 20	27,000	25—40	36	14	96	63	123	59	375	40	50	500
6	11 × 72	11 × 24	36,000	30—60	40	16	109	73	139	66	350	50	60	725
7½	13 × 90	13 × 30	60,000	40—75	48	18	116	73	144	120	350	60	75	1,040
8	18 × 135	18 × 45	89,000	100—150	48	20	156	90	164	132	350	125	150	1,450

* Makers' catalogue and correspondence.

The power required per ton will, of course, vary with the size to which the stone is broken, requiring additional power, to break it smaller than ordinary macadam.

An elevator and screen are used when it is desired to break everything down to $\frac{3}{8}$ inch.

If the product is not required smaller than $\frac{3}{4}$ inch, and some "spalls" are not objectionable, the screen and elevator are not needed.

Prices of Gates' breakers with revolving screen and return-elevator fitted complete, on frame; size 0, with 24 inches by 36 inches revolving screen, £156; size 1, with 24 inches by 36 inches revolving screen, £208; size 2, with 24 inches by 36 inches revolving screen, £250; size 3, with 24 inches by 36 inches revolving screen, £354.

Elevators 24 feet between centres, including connexions, range in price for the various size breakers (from 1 to 7) from £56 to £127, and weigh from 2,000 to 5,000 lbs. Revolving screens, with dust jackets, cost from £42 to £146 (exclusive of connexions) and weigh 2,000 to 8,000 lbs.

Medium-coarse and Fine-crushing.

From the point of view of the mechanical engineer the superiority of one machine of class II. over another, for the reduction of a certain kind of stone (say granite), can in a measure, be pretty easily demonstrated, but the question as a miner requires to look at it, becomes one of extreme complexity, as the factors to be dealt with are variable and conflicting, in more ways than one.

Viewed in this light, if the field of selection be limited, merely to the three classes of crushers particularized on page 233 the choice of the best for any special case, appears to depend on three equally important considerations, which are altogether outside the primary question of the mechanical merits or demerits of a particular machine, and it is here that the experience of the mining engineer is called into play.

To arrive at a trustworthy solution of the problem, he must take into consideration:—1st, the character of the ore itself and its associated gangue; 2nd, the degree of comminution to which it is desirable to carry reduction in order to get the best results out of any particular system of treatment that may be adopted; whilst in some cases, the location of the mine and the nature and position of the mill site, also form a 3rd factor of the question.

To put the matter in a nut shell and go a step farther, it may be laid down as a rule, that setting aside any other machines which have claims to attention, where one of the three classes of crushers (stamps, rolls, and roller-mills) now under consideration is found, commercially speaking, to best meet the needs of the miner in any one instance, it is most unlikely that either of the other two types, will be found suited to the requirements of the same case; if indeed, they did not turn out on trial absolute failures, supposing one kind of machine to be substituted for another.

An ideal "reduction plant," would have to establish a claim to extract the largest percentage possible of gold or other metal automatically in the shortest possible time, and in the simplest possible manner, combining capacity for expeditiously reducing the greatest quantity of ore in a given time to any desired point of fineness, with a minimum production of fines or slimes; it should further possess strength and durability without being cumbersome, and have as few working-parts and auxiliary appliances connected with it as possible. Now, while this acme of mechanical and metallurgical perfection combined has yet to be invented, the success of one type of crusher as against another in various instances, may be directly traced to the fact that some of those features which are wanting in one class of machine, are found more or less developed in one or other of its competitors. In selecting the most suitable machinery for his own particular object it is therefore incumbent on the miner not to lose sight of the points that have been indicated, as they may relatively affect in a different degree the circumstances he happens to have to deal with.

The adaptability of the plant in the foregoing respects, however, is not everything, as the outlay it may involve must after all be justified by the returns it will yield. He has therefore to compare :—

1. The prime cost and weight of each class of machinery, with its indispensable adjuncts for extracting the commercially valuable metals from any particular ore, representing a very variable capital outlay to produce a given result.
2. The simplicity or complexity of the entire plant in each case. not only with regard to cost of repairs, but also the time lost in maintaining it in running order in out-of-the-way places. difficult of communication, and where skilled labour is perhaps not available.
3. The relative time required to erect each different class of machinery; and lastly,

4. The comparative costs (both in regard to quantity and price) of labour, fuel, oil, etc., required to run a given class of plant in a certain locality.

Under these circumstances, with the limited data possessed at present in the shape of independent figures throwing light on many of these questions of relative efficiency and cost, at most only general statements can be made; and any attempt to assert the adaptability or superiority of one machine or class of machines for all cases, must infallibly break down.

Each form of crushing machinery has its champions and detractors who freely express themselves for or against it, according to the measure of success it happens to have achieved merely in their own limited personal experience; and where failure occurs the machine not unfrequently is blamed, when in some instances it is owing to want of forethought on the part of the purchaser in overlooking natural contingent results, which might have been reasonably foreseen and easily escaped.

The degree of comminution to which it is desirable to carry reduction to get the best results out of any particular system of treatment rests on the general nature of the process employed to extract whatever of value the ore contains; this is dependent to a very large extent on the ore itself and its associated gangue.

The choice of medium and fine-crushing machinery must then be regulated, from a mechanical standpoint, as well as by the class of ore it is required to crush, bearing in mind that ruinous losses may ensue by going to either extreme. That is to say, in selecting a machine, if crushing is carried to an unnecessary degree of fineness, money is wasted in doing unnecessary work, which shows itself in the cost sheet at the end of the year, besides risking various mechanical and metallurgical losses.

Amongst these latter, may be enumerated, slimes and fine mineral in suspension, in concentration, and wet amalgamation; dust in furnace and other dry processes; and various inconveniences in filtering and extraction, in those cases where ore has to be lixiviated; all entailing extra expense, to mitigate a difficulty which has been artificially created.

If, on the other hand, the crushing is not fine enough, a proper percentage of the metals (remaining as they do locked up in their stony envelopes) is not secured. So that whether water be employed to concentrate them, mercury to entrap them, chlorine to attack them, or some chemical solution to extract them, there is a more or less considerable loss, which ought to be carefully studied, for the purpose of finding the

vanishing point (so far as it can be learnt) common to all these combined sources of trouble.

One may say then, that there is a certain average degree of fineness, to which it pays best to carry reduction in every process (varying with the ore, and the method of treatment). But before this point can be settled it is necessary to decide what is the best process for the purpose in view, *i.e.*, in getting the largest commercial return on a given capital outlay.

On these grounds, it is of paramount importance that the chemical and physical peculiarities of the ore and its associated gangue should be first studied, and carefully noted in connexion with the local surroundings of the works, in regard to the character and cost of labour, fuel, supplies, and abundance or absence of water-supply, as well as climate and other considerations, which must influence the choice.

To enter into minute details concerning the peculiarities of various ores, and the processes of treatment they might be subjected to, is far beyond the scope of this paper, but from a general standpoint, as affecting the present question, the materials (ore and country-rock and gangue) which the miner, the metallurgist, and the mechanic, have alike to deal with, may be divided according to their physical characteristics, in three chief classes :—

(*a*) Brittle and hard; such as quartz, most pyritic ores, syenite, and coarsely crystalline metamorphic rocks.

(*b*) Tough ; such as native copper, gneiss, and most of the micro and crypto-crystalline metamorphic and intrusive volcanic rocks, which accompany ore-deposits.

(*c*) Soft or clayey; these latter comprising earthy carbonates, surface ores, or clayey limestones, as well as some classes of stone, comparatively hard and brittle like schist but carrying clay-partings, and sandstone.

When the different physical peculiarities which attach to the first elementary mineral substance in the above list are considered, it is seen what wide room there may be for enquiry in this direction alone.

Silica which possesses no doubt a special interest to many engineers when it takes the form of gold-quartz, may possess under certain circumstances, what miners term a kindly appearance, tinged sometimes a light-grey, blue, or brownish-red colour, combined with a dark resinous look; whilst elsewhere it may have a vitreous, wet, or opaque-white, hungry appearance, probably so-called by "cousin Jack," because it generally leaves him (if he attempts to work it) precisely in that very condition.

Still some of the best specimen-quartz is frequently milky, and white as a hound's tooth, whilst what is known as ribbon-quartz, a laminated variety of stone (separated by thin talc or chlorite-partings, or laminæ of graphitic shale or slate) is not unfrequently when met with, a good weight-carrier of metal. All these physical differences, due to peculiarities of hydration, association, and structure, will influence the way in which the stone breaks, and therefore affect its after treatment.

The materials dealt with by the mining engineer may, therefore, be divided according to their mineralogical characteristics and metallurgical behaviour, into a further number of classes, with different subdivisions:—

(*a*) Ores of the base metals, whether containing gold or silver or not, which have to be smelted or treated by a wet process, either with or without a previous (hand or mechanical) coarse or fine concentration, matting, or roasting, depending on circumstances which need not be enumerated.

(*b*) Ores of one or both of the precious metals, properly so-called, comprising:

1. Free-milling gold ores.
2. Free-milling silver ores.
3. Pyritic ores of gold and silver.
4. Combinations of 1, 2, and 3.
5. Exceptional ores.

These different kinds of ore may be subjected to various processes, amongst the most general of which, for dealing with free-milling* low-grade gold ores (belonging to class 1) are:—

1. Stamping the ore wet to fine size, and catching the free gold on copper plates (inside and outside the battery), with wells and mercury traps, used as accessories.
2. Wet stamping the ore coarse, and amalgamating on copper plates, separating the coarse-sands from the finer slimes, by screens or sizing-boxes (in some cases, preceding or following this separation by fine concentration); and regrinding the coarser sands thus saved, in Huntington or Chilian mills, or pans;† followed by more copper plates.

For dealing with free-milling comparatively high-grade ores of gold, belonging to class 1, in which there is an excessive loss, if the previously described systems of treatment are followed (owing to the fine

* A term implying that the greater part of the gold is free.

† Without mercury preparatory to re-amalgamation.

state of division of the metal, its alloyage with silver, or some other reason) there may be employed :—

1. Wet stamping, succeeded by direct pan-amalgamation on the ordinary plan (or else what is known as the Boss continuous system); or crushing dry (followed in exceptional cases by roasting) and then amalgamating in Chilian mills or pans. When there is a small percentage of rich sulphides present (especially if dealing with a mixed gold and silver ore) fine, *i.e.*, table-concentration, may precede or follow the pan-treatment with an appreciable saving.
2. In a few special cases, like the Mount Morgan mine, Queensland, ores of this class may no doubt be treated in bulk with advantage by drying, crushing with rolls, partially roasting, and working by chlorination in barrels. That the Mount Morgan ore may equally well be classed amongst the exceptional ores (belonging to class 5), becomes evident however, when the facts of the case are closely studied.

Mr. T. A. Rickard in a paper read before the American Institute of Mining Engineers, June, 1891, says :*—"The complete success of the treatment is largely due to the extreme friability of the ore, which renders its pulverization easy, whilst its porosity assists materially in the thorough chlorination of the gold." An enthusiastic writer has spoken of the ore as a sort of snow-drift, which melts in the chlorination vats of the company, into a golden sand, such as might be supposed to have been brought from the bed of the river Pactolus, instead of from the top of an Australian mountain. The extreme richness of the stone hitherto available for treatment in large quantities (the capacity of the works being 1,800 tons per week), the extremely minute state of subdivision of the gold, and the physical peculiarities of the ore above referred to, have all tended to make barrel-chlorination applied in this peculiar way a success, where the stamp-mill has been unsuccessful, and this also accounts in no small degree for successful crushing of the ore with rolls.

Mr. Rickard remarking on the cause of failure when the ore was stamped, says :—"The rock which the battery (25 stamps at Dee Creek) was called upon to crush, averaged 10 ounces per ton, but the contents of the tailings proved of much greater value than the amount of amalgam obtained. This led to a critical examination of the ore at the Sydney Mint." It was found that the bullion was of a fineness hitherto unknown in nature, assaying 99·7 per cent., occasionally 99·8 per cent., of pure

* *Trans. Am. Inst. Min. E.*, vol. xx., page 150.

gold, the rest being copper with a trace of iron. It is remarkable as being almost entirely free from silver. Dr. Lebius, of the Sydney Mint, considered as a result of numerous experiments, that the iron present was in the form of an oxide, which coated the gold, and so prevented its contact with mercury. In a footnote Mr. Rickard adds: "My own experience with the ores of Gilpin County, Colorado, leads me to believe that this is more frequently the obstacle to successful amalgamation than is usually supposed.

For dealing with free-milling silver ores (carrying less than 6 ounces per ton of white metal) belonging to class 2 as a rule one may employ :—

1. Wet stamping, followed by direct amalgamation in pans or barrels. The ores of this class are limited, only embracing decomposed surface-ores, carbonates, and occasional deposits of argentite, chlorides, chloro-bromides, and native silver.

For dealing with pyritic ores of gold and silver, belonging to class 3 which contain the larger proportion of their metallic contents in combination with sulphides. The following are the usual methods :—

(*a*) If the sulphides are massive.

1. Hand-picking and after treatment, as described below.

(*b*) If the sulphides (pyrites) are disseminated.

2. Wet stamping, combined with battery and plate-amalgamation, to extract the free gold followed by fine concentration of the pyrites, and treatment of the hand-sorted ore and concentrates by smelting for lead, which yields bullion that has to be refined by different processes; or by smelting for copper in reverberatory furnaces, to produce an enriched copper matte.* The choice of these methods depends on whether lead or copper is the predominating metal. More frequently, however, the gold is extracted from the concentrates by the ordinary Plattner vat-chlorination treatment, whilst in a few special cases an iron matte is produced, and sold to smelters, or crushed and chlorinated.
3. Wet stamping, followed by amalgamation and fine concentration, and grinding the concentrates raw, in pans or Chilian mills.
4. Dry stamping, followed by roasting, with or without salt, and amalgamation in pans or barrels, a process which is only adapted, however, as a rule, to rich silver ores, carrying a certain proportion of sulphides, but not enough to pay for concentration.

* The gold and silver in this matte, are subsequently extracted by a wet process from the copper-bottoms which contain the gold, after the silver has been extracted by the Ziervogel or Augustine processes.

5. The new cyanide-lixiviation-process, which is claimed to be applicable to the treatment of certain gold ores, much in the same way as the Russel process is to silver.
6. Ordinary lixiviation.

Dealing with ores belonging to class 4, which are amongst the most difficult to treat, because a process adapted to the extraction of gold may be very inefficient for the recovery of silver, and *vice versa:* when one metal is in small proportion as regards value, it is frequently sacrificed to the most profitable process commercially for the other. Many of the base silver ores of the United States contain 5 to 15 dwts. of gold, and from 20 to 50 ounces of silver per ton. For such ores dry stamping, roasting, and pan-amalgamation is mostly used, and under proper conditions will extract 90 per cent. or more of the silver, but only 40 to 60 per cent. of the gold. Lately, however, coarse-crushing, instantaneous roasting in Stetefeldt furnaces, and double-leaching by the new Russel process has come into prominence, and is said to be giving excellent results in certain instances, as regards economy and extraction of both metals.

The Russel process seems to be more particularly applicable to those ores which do not contain enough lead or copper for smelting, are poor both in gold and silver, and which contain large amounts of sulphur, arsenic, and antimony, since roasting with salt would convert the base metals as well as the silver into chlorides, and would give a very base bullion if it were amalgamated. There is, however, a remedy for this, which Mr. McDermott points out*: "When the silver is in combination with sulphides, antimonides, arsenides, and tellurides of the baser metals, the pan process becomes inefficient and expensive. By contact with iron surfaces, heat, and the addition of some chemicals—chiefly salt and sulphate of copper—a partial decomposition of the complex minerals is effected, and some of the silver amalgamated, but the wear of iron, loss of mercury, cost of power and chemicals, and the production of base bullion together, go far to neutralize the gain made in the recovery of the silver. In such a case a great benefit is derived by combining concentration with amalgamation. The light, flocculent chlorides and sulphides of silver can be amalgamated to a high percentage, while concentration is almost useless to deal with them in the form in which they exist in a free or decomposed ore.

On the other hand, concentration can be made very effective on the undecomposed complex minerals, for which amalgamation is ill-adapted.

* *Gold Amalgamation*, by Walter McDermott and P. W. Duffield, page 88.

There are two methods of combining the processes according to their order, concentrating either before or after the pan-treatment. In regard to the relative advantages of the two, concentration before amalgamation is the natural method, because it relieves the pans of the baser minerals, which are a disadvantage in the amalgamation, and the subsequent concentration of which is made more difficult by the grinding or attrition of the minerals in the pans.

The only argument against the universal adoption of this order, rests on the disadvantage of sometimes having native metals, and some chlorides and sulphides entering the concentrations, instead of appearing at once as bullion, which they otherwise would do, and also, that very perfect settling of the slimes from the concentration tails is necessary, to prevent loss of the flaky silver chlorides and sulphides. This process is in use at the Standard mill, California.

When the free metal is gold, the first-named disadvantage can be overcome by using copper plates before the concentrators, and this process was adopted by the Montana Company with great success, after first trying pans before the concentrators.

Comparing the combined process with dry crushing and roasting, the advantages of the former consist in a reduction of the cost of working fully one-half of that of dry crushing, a crushing capacity of double for the same number of stamps, a decreased cost of erection, and a higher saving of gold present. Against these advantages may be placed simply the increased percentage of silver saved by the dry process under certain circumstances.

When combined gold-and-silver ores carry over 10 per cent. of base metals it usually happens that the silver does not exist equally in the minerals present, but is concentrated in one of them as a rich, brittle ore. It follows from this, that concentration in some instances is very ineffective, because while 90 per cent. of the heavy base metals may be saved in the concentrates, the loss of the fine silver-bearing mineral in the slimes may be fully 50 per cent. of the assay-value of the crude ore. In some cases the clean concentrated, heavy minerals do not assay more than the original ore from which they were separated.

This is a very strong argument against the injudicious application of fine concentration to all cases, for, as Mr. McDermott says, there are ores of both gold and silver in which the sulphides are so rich, that even a very small loss by weight involves a very large loss by assay of the precious metals.

Such minerals as tellurides of gold and silver, ruby and brittle silver

ore, come under this head. In concentrating some of the tellurium ores of Colorado, some of the very finest slime-material, overflowing from the concentration-tanks of the Frue vanners, assayed as high as £5,000 per ton in gold and silver.

Where there is danger of loss, as described, it is advisable to introduce a double concentration, re-treating the tails on vanners.

For dealing with exceptional ores belonging to class 5: if their value lies mostly in tellurides of gold and silver, with little or no sulphides present, the most successful method yet found is by selection of the rich ore; and concentration (as above described), by double treatment of the low-grade ores. Both rich ore, and concentrates, are then so valuable, that smelting on the spot or shipment to smelters is advisable.

Another class of exceptional ores are those, in which the gold is not free, so far as tests indicate, and yet there are no sulphides present.

These ores are generally oxidized in character, changed from their original form, and contain chloride of silver in addition to the gold. As some of these ores, when leached with hyposulphite of soda, yield a large portion of the gold as well as the silver, it would seem to indicate that the gold exists as a chloride, combined with the silver, either as a double insoluble chloride, or mechanically protected by the latter from being leached out by the natural drainage-water of the mine. Such ores are uncommon, but have been worked to some extent by a raw-leaching and concentration for the fine carbonate of lead, and its combined silver which is also present.

There may be, other explanations, however, to account for the peculiar character of the ores just alluded to. On page 6 of *Gold Amalgamation and Treatment*, the losses of gold in milling are referred to five principal causes:—

1. Loss of free gold, quicksilver, or amalgam, due to carelessness or inexperienced amalgamation.
2. Free gold and gold-bearing sulphides, attached to or embedded in particles of rock.
3. Gold contained in base-metal sulphides, broadly termed sulphides.
4. Gold lost in fine slimes, and sometimes in solution.
5. A condition of gold in which it is not susceptible of copper-plate amalgamation.

It is with the last of these that we now have to deal.

Quite recently * Mr. Richard Pearce, of Argo, Colorado, has given

* "The Association of Gold Ores with other Metals in the West." *Trans. Am. Inst. Min. E.*, vol. xviii., page 447.

some most interesting facts with regard to the association of gold with other metals in Colorado, which bear on amalgamation and concentration. His investigations go to prove that gold and silver exist in some of these ores found below the water-line, alloyed with bismuth, tellurium, and copper, and perhaps arsenic, where the presence of such combinations has hitherto been unsuspected, and a coarse-grained almost pure pyrites containing silver and a small value of gold, from the Louisville mine of Leadville, has been proved to contain metallic tellurium. When thus combined the gold would appear to be more or less refractory to the ordinary milling treatment, and this may account for some of the troubles set down to so-called rustiness.

A natural crystalline compound of gold and bismuth, has lately been discovered in Australia, it is said, and native alloys of these metals are known under the names of maldonite and bismuthaurite. Hessite, a natural combination of tellurium and silver (Ag_2Te) has been found in some of the Red Cliff veins, and a telluride of bismuth, probably tetradymite was found by Mr. Pearce in ore discovered at Ouray. He contends that, in certain cases, bismuth performs, a by-no-means small part, in influencing the general deposition of gold, and also in causing the refractory behaviour of this metal under metallurgical treatment.

Mr. Pearce adds: "The occurrence of gold in this district seems to be intimately associated with that of eruptive porphyries, and the impregnation of veins with gold-bearing minerals is apparently always accompanied with silica. Evidence of intense thermal action* is one of the chief characteristics of gold deposits. Examples of these processes may be found in Gilpin, and also in Boulder County. In the latter district known as the 'telluride Belt,' there are indisputable evidence of vein-impregnation by the circulation of siliceous waters through the joints of the porphyry; in this case tellurium is the chief mineralizing agent of the gold. Perhaps the most striking example of the deposition of gold, through the agency of thermal waters, may be seen in the celebrated Bassick mine, which has so often been described. This deposit exhibits all the characteristics usually accompanying geyser action. The disintegration of the porphyry, with a partial replacement of the felspar by silica, is here clearly shown. The gold was combined almost in its entirety

* The idea Mr. Pearce intends to convey (which is the writer's view of the matter) is that the filling of veins with mineral, is rather due in most cases to the leaching of the adjacent rock-masses, followed by a gradual replacement of the original constituents of the lode with ore, along certain horizons or belts, than to the action of thermal waters, building up masses of mineral in an open fissure, though both solfatara action, as Mr. Pearce remarks, at the Bassick mine, and sublimation in exceptional instances, may have tended to such a result.

with tellurium, and rich tellurides of gold and silver were found sprinkled through the mass of material. In some remarkable specimens these tellurides formed a distinct coating on the surface of smooth boulders which had become rounded by attrition from the action of steam."

Dr. T. Egleston, in an elaborate paper on the causes of rustiness and some of the losses in working gold ores,* points out that the term rusty is used by miners to indicate a condition in which the metal is supposed to be coated superficially or alloyed with some substance, which prevents contact with mercury, and consequently precludes the possibility of amalgamation.

Gold in this state, it appears, is frequently covered with a brownish coating, which has a much redder colour than ordinary gold, and is irregularly distributed over its surface: where the least abrasion has occurred the metal underneath show the true gold colour. Fine particles of gold are sometimes visible with the microscope in the detached coating, and it often cracks off from pieces of gold, leaving them bright. Very often this film is composed entirely of silica, deposited on and beside the gold. It is sometimes opaque, and again quite transparent, so that the gold can be seen with the microscope disseminated through it, just as cinnabar-crystals are seen in the red chalcedony of the district around Knoxville, California. There may be, for example, many artificial causes which produce this rustiness of gold, the covering of the surface with particles of some foreign substance, or its alloyage with other metals, as already explained.

As Mr. McDermott remarks, concentration and pan-amalgamation would probably be effective on the former class of ores, though for reasons that will presently appear the writer would like to add, or concentration preceded by crushing in centrifugal roller-mills, if other circumstances admit of it. Dr. T. Egleston's view is, that the action of rubbing, which occurs in any machine like the arrastra, is much more likely than the stamp-mill to pulverize the fine pyrites, break up any coating that may be around the particles of gold, rub off the superficial deposit, and thus bring the gold into contact with the mercury and make it amalgamate. He states, as a remarkable fact, that in the early days, Mexicans with the arrastra, got 50 to 60 dollars a day, where stamp-mills, working the same rock, only obtained 15 to 20 dollars, and instances can be cited where, with the best modern machinery, only 20 to 30 dollars can be got out of rock which yields 700 to 800 dollars by fire assay.

* *Trans. Am. Inst. Min. E.*, vol. ix., page 646.

Of course this might be due partly to the first cause of loss cited, viz., carelessness or inexperience on the part of the workmen running the mills, but this is on the whole unlikely. Amongst other causes in the treatment and composition of ores which render gold un-amalgamable in the mill, and which have to be considered and guarded against, Dr. Egleston mentions :—

1. Gold which has been hammered, so as to increase its density and close its pores, amalgamates very slowly, a condition, however, which can scarcely be taken into account in the working of a stamp-battery, unless the gold is very coarse.
2. The presence of sulphuretted hydrogen in the water, likely to be induced by the presence of soluble sulphides.
3. Gold which has been exposed to the vapour of sulphur, which no doubt accounts for the behaviour of certain ores when submitted to amalgamation after roasting, and the same is doubtless true of arsenic in some instances, judging from Mr. Pearce's conclusions.
4. Certain alloys of gold, like the phosphide, though others like the arsenide and antimonide (produced artificially) are apparently more tractable. To these alloys must now be added the bismuthide, telluride, and cupride.
5. Greasy substances, like powdered natural hydrated silicates of magnesia and alumina, if present in the ore, froth and coat the gold with a slime, preventing the action of the mercury, and lubricants such as oil, getting into the battery box, are fatal to gold amalgamation.

The late Mr. E. N. Riotte once mentioned in the writer's presence a case within his experience, which occurred at a gold mine in one of the Southern States, where they had to abandon the use of dynamite on this account; as owing to the inexperience of the negroes in its use, portions of unexploded cartridges were left in the stone, and affected the battery yield. The result, if the nitro-glycerine had leached out, and collected in a corner of the box, would doubtless have been a revelation to them.

6. Unusually soft water, absorbing air or carbonic acid gas, and so tending to form ferric sulphate (when pyrites is present), which is a most active agent in staining the plates.

Glancing back at the processes that have been referred to, it will be seen, that except in dealing with free-milling silver ores and a few special cases, there is considerable latitude given in the choice of a process, not to mention its details.

Its proper selection will depend on considerations of relative cost, as compared with saving or loss of metal, or other valuable products, that the ore contains; and nothing influences both of these in the same way, or either of them more, than the degree to which the crushing of the stone is carried, which is the author's next proposition.

The finer the crushing, and the more the ore is handled or re-handled, by repeating the operation, the greater of course will be the expense; while the more it is handled and the finer it is crushed beyond a point that is absolutely necessary, the greater also will be the loss. To reduce this latter to a minimum, a certain cost must naturally be incurred, though if it go a little too far, the cost is increased and the loss as well.

This happens under various circumstances, viz. :—

A. In coarse concentration of the baser metals and of gold and silver ores, or a combination of both (applicable to the latter classes of ore, when the sulphides exceed say 10 to 20 per cent. by weight) to obtain the mineral with a minimum loss from comminution, the ore must be broken up, only just enough to unlock all the mineral it may contain, down to a certain size, and (theoretically) the mineral and barren rock with it should be separated at once. This will leave, however, a certain amount of yet more finely divided mineral in the residues, which require to be re-crushed and re-treated at so much additional cost, to get out the metal that remains in them, less of course a certain percentage of loss involved in this re-treatment.

When coarse combined with fine-concentration is necessary, it may then be considered how far it will pay, to carry theory into practice, and when labour is cheap, the life of the mine assured for a long period, and the ore of considerable value, the German practice may be adopted, of classifying carefully, reducing the ore gradually, and concentrating close; but when labour is dear, the life of the mine uncertain, and the chief object is to secure the largest possible profit in the shortest possible time at a minimum capital outlay, irrespective of a certain unavoidable loss in unrecovered mineral, the Anglo-American method must be adopted of sacrificing saving of mineral, to saving of cost and time, and crush the ore in quantity, to a much greater average degree of fineness, without such careful regard to sizing it.

The latter practice is the one followed in most American and colonial mills, employing fine concentration for gold and silver ores (when the sulphides in the ore do not run over, say, 10 per cent.). To compare

these divergent systems roughly as to cost, two different cases, one of a European zinc-and-silver lead-mine, the other an American lead-mine may be taken.

The works in Europe are those of the New Pierrefitte Co., which the writer was commissioned to inspect last summer, and of which he is permitted to give the following particulars :—

They are situated in the Pyrenees in France, and treat an ore containing galena, blende, magnetic iron, and a small amount of copper pyrites.

On an output of 21,449 tons of crude ore last year (averaging 9·33 per cent of silver-lead, and 11 per cent. of zinc) the cost of dressing, covering wages, supplies (including coal for three months of the year, water-power being used for the remainder), renewals of machinery, etc., may be taken at about 3s. 10d. per crude ton, as given below :—

Continental Works.	Per Crude Ton. Francs.	American Works.	Per Ton. Cents.
Labour	... 2·35	Labour	... 13·4
Supplies and repairs	... 2·43	Supplies	... 3·5
		Repairs	... 10·0
		Coal	... 9·5
Total	... 4·78 = 3s. 10d.	Total	... 36·4 = 1s. 6¼d.

The American case is that of the new dressing works of the St. Joseph Lead Co., at Bonne Terre, Missouri.* The ore is non-argentiferous galena, associated with some iron pyrites, carrying traces of nickel and cobalt. On an output of 224,203 tons of crude ore in 1886-1887, averaging 5·65 per cent. of galena, the cost of dressing for the fiscal year, ending May 1st, covering labour, supplies, repairs, and coal, was (1s. 6¼d.) 36·4 cents, divided as above shown.

It would take too long to explain the differences of treatment in the two mills, suffice it to say, that the system outlined in both, is to crush with rock-breakers and rolls (preceded at Pierrefitte by spalling and cobbing), and then to jig and wash the ore on tables and buddles. The difference mainly is, that in the one case they give attention to sizing, and in the other they do not, though each mill in detail possesses certain peculiarities of its own. Neither can the relative number of workmen, cost of wages, supplies, etc., in detail be compared, as these data in the cost sheet are wanting, in the otherwise excellent paper quoted, from which the particulars of the Missouri mill are taken. In the French works, wages range from 1 fr. (10d.) to 2 fr. (1s. 8d.) for boys, and 2·75 fr. (2s. 2½d.) to 3 fr. (2s. 6d.) per day for the larger number of adult

*Trans. Am. Inst. Min. E., vol. xvii., page 659, H. S. Munroe.

mill hands, and it is noteworthy that in both mills repairs and supplies (excluding coal from the American case) bear nearly the same ratio to one another.

It would appear at first sight, that all the advantages lay with the American mill, and no doubt it does in America, where labour is dear, with the base ores that have to be dealt with in quantity, where the works are situated. The case, however, would be entirely different if the American mill were transplanted to the Pyrenees, and set to work the silver ores of that locality, as the loss in the tailings at Bonne Terre is about 2·13 per cent., or 27·4 per cent. of the total amount of lead in the ore. These large losses are due to included mineral in the coarse-sands, and to very finely divided mineral in the very fine slimes, as a large part of the ore requires very fine crushing, owing to the exceedingly minute state of division of a large part of the mineral.

In the Pierrefitte works such losses with argentiferous galena could not be afforded, and though the writer is not in a position to state what they are exactly, they are far less than in Missouri. Moreover, the cost in the Pyrenees, with a larger output from the mine, could be materially reduced, as the works are not run up to their full capacity, and if their general design could be remodelled on the lines of more modern Continental mill-construction, the expense of treatment (if carried out on a similar scale as regards quantity) might, be made to compare more favourably with the price in America without sacrificing mineral, in view of the lower price of labour.

To again quote Prof. Munroe, the losses in the Lake Superior copper mills range, it is said, from 28·5 to 31 per cent., treating mineral much more easily saved than the Bonne Terre galena, whilst the cost of dressing copper at the Atlantic mill in 1885, using steam stamps, is stated to have reached 30·36 cents (1s. 3½d.), divided between labour, 5¾d.; fuel, 7¼d.; supplies, 2½d. These costs were reduced, however, at the Atlantic mine in 1887 to 27·5 cents or 1s. 1¾d. per ton of copper ore treated. Incidentally, Prof. Munroe states it is cheaper to crush ore* with rolls, arranged as they are in the Bonne Terre works, than the Lake Superior amygdaloid with steam stamps, but this is partly due to the friability of the Missouri ore; what is far more remarkable, however, is that the rolls produce (according to the Professor's statement) quite as large a proportion of slimes as the steam stamps.

Further, it should be noticed that the above instances of the cost of concentration in America are to be looked upon as a good deal below the

* Limestone.

average (at any rate of smaller mills), and as a general rule, coarse concentration, where rolls are employed for crushing, does not cost far short of 75 cents or 3s. 1½d. per ton, where labour rates are dear.*

The average cost of dressing different classes of ore in France is given by Dr. Foster and Mr. Galloway† (from a statement of Mr. Huet) as:—

	Per Ton. s.	d.
Iron ore	0	2
Coarse-grained galena	5	10
Fine-grained galena	7	10
Manganese ore	7	10
Copper pyrites, or grey copper ore with iron pyrites	9	9½
Coarse galena and blende	9	10
Fine galena and blende	11	10
Copper pyrites, or grey copper ore with galena ...	13	10
Copper ore, galena and blende	20	4

Though these figures may have been typical and true of French practice at the time they were compiled, the dressing-costs at Pierrefitte would indicate that they are much above the average at the present time; and, as the translators remark, there is always great uncertainty in estimating such working costs in a general way, for there is always uncertainty with reference to the labour required for shifting the stuff about, and principally with reference to the loss in dressing, to which might be added the attention required by different classes of machines when differently grouped.

If the American losses in dressing be compared with those in Germany it will be seen that the advantage rests with the Continental system.

Oberbergrath O. Bilharz, in a paper entitled "Die Neue Central Aufbereitungs-Werkstätte der Grube Himmelfahrt, bei Freiberg i.S.," puts the losses in the tailings of these works, at only 0·01 per cent. silver, *nil* per cent. lead, 10 per cent. sulphur, and 9 per cent. zinc. While the settlings in the final catch-pits‡ carry only 0·01 per cent. silver, 2 per cent. lead, 8 per cent. sulphur, and 6 per cent. zinc.

Quoting the pamphlet referred to, the transcript of an article from *Industries* (in the *New York Mining Journal* of February 20th, 1892) and the writer's personal knowledge, he would like to refer to the Freiberg works more particularly, because he thinks they are illustrative of American principles, so to speak, engrafted upon former German practice,

* In exceptional cases the price may run up to 12s. 6d.

† *Lectures on Mining*, by J. Callon, vol. iii., page 134. Translated by C. Le Neve Foster, D.Sc., and W. Galloway.

‡ Only a fractional portion of the crude ore, which is re-treated.

presenting a model of economy in costs, as well as economy in saving of mineral, to an extent which has never been achieved before, an advance which is undoubtedly in the right direction.

The ores which are obtained from the various shafts of the Himmelfahrt mine consist of argentiferous galena and zinc blende, with iron, copper, and arsenical pyrites, while the gangue is partly quartzose, partly sparry, mixed with the country (gneiss).

On account of the variety of the ores of the Freiberg district, the machinery of the dressing-floors is duplicated, so that ore from other mines can be dressed apart in the two sections, into which the mill is divided.

The annual production of the Himmelfahrt mines alone is 45.000 crude tons, of which four-fifths is concentrating ore, coming from what is known as the pyritic-lead formation (kiesige Blei-Formation) the remainder being rich silver ore and high-grade hand-picked galena ore, found mostly in cross-courses, carrying a gangue of brown spar and heavy spar.

These latter ores, representing one-fifth of the total production, are separated dry (hand-sorted and dry-stamped) and sent direct to the smelting-works.

The dressing-floors* are designed to handle 150 tons of pyritic ore per shift of ten hours, each separate section dealing with 75 tons, with an average total consumption of 35 cubic feet of water per minute, the machinery being driven by steam-power.

The ore averages 0·15 to 0·20 per cent. silver; and iron pyrites and galena are the predominating minerals. The zinc blende is black, and contains 33 per cent. of iron. The building is arranged in storeys, one above the other, and contains rock-breakers, screens, hand-picking tables, several sets of rolls, wet gravitation-stamps, a variety of revolving screens and jigs, hydraulic classifiers, Stein vanning-frames, and other machinery (fully described in the papers referred to) which present many novel features of detail.

The horizontal compound-condensing engine which runs the whole crushing, dressing, and electric-lighting plant, indicates 105 horse-power, and the works employ 44 workmen, with 3 overseers, 1 engine-driver, 1 stoker, and 5 fitters, in all 54 men.

The cost of dressing one ton of ore amounts to 10d.

* The machinery was built and erected by Mr. C. Luhrig, of the firm of Messrs. Luhrig, of Dresden, in accordance with the plans of Mr. O. Bilharz, who designed the installation.

There are only, five points which could be charged against the plant taken as a whole :—

1. That the design involves a considerable capital outlay (an objection, which it will be shown later on, is entirely swept away, when it conduces to and results in economy of treatment, provided that the mine warrants it, and that the working capital of a company can stand the necessary call without stinting the development of the mine.)*
2. That it may be doubted whether efficient roller-mills of the Schranz type, might not advantageously be substituted for the stamps.
3. That, large as may be the reduction in labour as compared with many other Continental plants of the same capacity, it might be still further lessened, given a better site than the one at Freiberg, which possesses but a moderate fall.†
4. That owing to the nature of the machinery, several skilled machinists, as well as facilities for making repairs on the spot, are very essential for running it properly.
5. That if anything goes wrong with any of its individual parts, the whole plant appears to be brought to a standstill. The writer was reminded of this by the practical illustration of a belt slipping off a pulley whilst he was going through the works two years ago. It is a matter, however, which is capable of remedy.

On the whole the advantages far outweigh any objections that can be urged, and the structural details of the plant, and erection of the machinery exhibit first-class skilled workmanship.

The stock required to be kept on hand in concentration-works consists of duplicate parts of the machines, in more or less number, (depending on the distance from a source of supply and the average life of the different pieces in use).

The proposition stated on page 255 holds good.

B. In the fine concentration of sulphides (which generally accompany the precious metals) on belt or other automatic concentrators, which are so frequently used‡ as an adjunct to the stamp-battery.

* As these works are a Government concern, this last consideration may in the present case be dismissed.

† Owing no doubt to its being the only site available on account of other reasons.

‡ Before adding concentrators of this kind to a mill, it is of course necessary to ascertain that the clean concentrates will assay enough to leave a profit on further local treatment, or shipment, to extract the gold, silver, or other metals they may contain.

The size to which the stone is reduced under such circumstances influences very largely the chance of loss of mineral and gold, whether included in the coarser part of the tailings, or liberated as fine slime.

The cost of the actual mechanical fine concentration is not a matter of extremely serious consideration in itself, since assuming 18 tons of concentrates saved *per diem* in this way, crushing an ore containing 2½ per cent. of pyrites, the cost of treatment would not exceed 2d. or 3d. per ton, and dealing with much smaller quantities, 6d.; and further it will not vary much whether the ore is stamped coarse or fine, unless it involves a double concentration (that has been alluded to) dealing with rich ores liable to slime. But in order to concentrate in this way the ore must be stamped wet, and what applies to crushing fine with rolls, is also true of stamps. The finer the crushing the more it must cost in time, representing extra labour and a wear-and-tear, and also fuel, etc.

C. In stamping previous to grinding in pans, if carried too far, there will again be loss in the battery-tails, whilst if not carried far enough, it will give the pans unnecessary work to perform, which would be much more cheaply done in the battery.

D. When the concentrates are treated (obtained by coarse or fine concentration or both combined) by such processes as smelting, chlorination, and lixiviation, it will be found that, if it involves a preliminary roasting (as these processes generally do), if the ore is crushed very fine, and it carries much lead for instance, it entails a more careful regulation of the temperature, and unless a suitable type of furnace is used, with extensive dust chambers attached, great losses both mechanically and by volatilization may be incurred. On the other hand, if the ore is not crushed fine enough, and it is subjected to a chloridizing roasting with salt, the chlorination will not be as high as it should be, and the subsequent treatment will be proportionately affected by it.

E. If the ore is to be lixiviated or chlorinated, and the stone is crushed too fine, and at the same time of too uniform a grade, great loss of time and imperfect filtration and leaching will result, more especially if it is at all of a clayey nature.

The choice of a process, whether for treating crude ore or concentrates, must be governed by the relative commercial profits it promises, as compared with other methods of treatment. But before attempting to touch

this question, it will be advisable to state certain general facts (under separate headings), giving an outline of several of the processes, which are later on compared, under the head of rival methods of ore-treatment, in order to simplify the subject.

Roasting and Chlorination.

This is, ordinarily the best process to employ, for the treatment of the high-grade pyritic concentrates of stamp-mills, and hand-picked sulphide ores, provided a sufficient quantity can be commanded to run the works full-time or nearly so; intermittent work being bad for plant as well as for men. The ore should be kept moist after concentration, till it goes to the drying-floors, as otherwise lumps will form which will not roast properly unless re-crushed.

The ore to be roasted is generally worked in reverberatory furnaces to expel the sulphur, arsenic, and other volatile compounds till it is dead sweet or as nearly so as possible. Then a small quantity of common salt is added, and the silver is chloridized, the sulphur is all driven off, and the ferrous and cuprous sulphates are oxidized.

The ore having been damped to about 6 per cent. is gassed with chlorine, a trichloride of gold being formed, which is leached out and precipitated with a solution of sulphate of iron. This gold is collected on filters, thoroughly washed, dried, and melted, and should average from 998 to 999½ fine.

When silver is present in sufficient quantity to justify the extra treatment, it can be recovered by re-leaching the residues with hyposulphite of soda or lime to dissolve the chloride of silver, which is precipitated from the lixivium by the addition of a solution of polysulphide of sodium or calcium, and the sulphide of silver resulting (collected on the filters) is washed, dried, and reduced to the metallic state.

There is, however, one point to be guarded against in adopting this latter mode of treatment in dealing with ores, in which the percentage of gold is high, and about equal to the silver.

Kustel,* remarks:—"If such an ore should be subjected to chloridizing roasting, then impregnated with chlorine gas, leached with water for the purpose of extracting the gold, and finally leached with hyposulphite of lime for precipitating the silver, it would in this case, although a high percentage of silver might be extracted, result in a yield of gold that would hardly amount to 50 per cent., more or less.

* *Roasting of Gold and Silver Ores*, by G. Kustel, second edition, page 123.

The reason is not easily explained. The gold may be influenced somehow by the base-metal chlorides during the roasting, which prevents the gold being attacked by the chlorine gas."

On the other hand, if the base-metal chlorides and the chlorides of silver are extracted previous to the impregnation with chlorine, both metals, silver and gold, can be got out very close by a process invented and patented by O. Hofmann, which Kustel fully describes in detail.

The gold and silver-bearing sulphides of the Colorado No. 2, G. and S. M. Co., at Monitor, Alpine County, California (as an instance) were successfully treated by this method.

Should the sulphides contain any lead, it is advisable to conduct the liquor from the leaching-vats to settling or storage-tanks, and about 40 lbs. of sulphuric acid (66 degs. B) is added. By this addition the lead is precipitated as sulphate, and the liquor, being freed from lead, can yield no plumbic sulphate with the gold, as it would otherwise do, when precipitated with sulphate of iron; hence a cleaner bullion.

In some chlorination works,* as the sulphate of lead obtained from the base tanks, always contains some gold, it is collected and sold, and a considerable sum is then realized for both lead and gold. The wooden tanks are protected from the action of the acids, by a coating of paraffin paint; and the covers of the chlorination-vats are luted on with a mixture of tailings, bran and water.

There are certain pyritic ores, however, to which chlorination is unsuited. These include amongst others :—

1. Ores of low grade, which run below, say £3 to £4 value per ton.
2. Those in which the gold is very coarse.
3. Those in which there is any mineral present, or other metal except silver and gold, in the gangue, liable to be attacked and rendered soluble by the chlorine, whilst gold must be either in a metallic state, or in a combination which can be destroyed by roasting without loss.

The impurities most to be avoided are sulphur, antimony, and arsenic, since soluble salts of the base-metals may precipitate the gold in the leaching-vat; hence the necessity of what is termed a dead sweet roast before-mentioned. Lead, lime, and magnesia are also deleterious, as they are attacked by the chlorine, and waste a great deal of it, besides introducing difficulties in the after-precipitation.

Mr. Nelson E. Ferry, M.E., in the *New York Engineering and Mining Journal* of November 28th, 1885, recommended the addition of molasses

* *Eighth Report of the California State Mineralogist*, page 47.

to the leach when lime was present. Mr. Ferry says: Dissolve one gallon of molasses in 30 or 40 gallons of water and keep for use. The quantity to use in each case must be determined by a laboratory test. If calcium sulphate comes down, either the molasses is in insufficient quantity, or it has not been thoroughly mixed. Examine by transmitted light. Avoid large excess of ferrous sulphate. If the gold comes down at first in a flocculent state, that does not matter, it soon assumes the usual form. The best results are got when the liquid is made slightly acid.

Mr. A. H. Aaron* recommends the use of precipitated copper sulphide as a precipitant,† stirring it into the gold solution, or better, allowing the gold solution to flow through a series of small filters containing the sulphides. He states as a reason that, unless there is copper present to precipitate it, there is often a considerable loss from gold in suspension, due to imperfect settling.

The presence of galena, necessitates a good roasting with a strong finishing heat, as far as its fusibility will allow. This involves the use of a long hearth to raise the temperature gradually, as the charge progresses from one end of the furnace to the other. The roasted ore must be examined to see that no galena is left undecomposed.

Any soluble iron chloride or other soluble metallic salt formed, will react on the iron oxide and precipitate the gold, when dissolved, leaving it in the tails of the ore-tanks after lixiviation. The addition of a little salt towards the close of the roasting, after the ore has been carefully oxidized, tends to counteract the effect of the lime and magnesia so often present in gold and silver-bearing rocks.

Concentrates frequently contain iron as well as copper pyrites, galena,

* *Notes on the Hydro-metallurgy of Gold.*

† Mr. Claude Vautin, whilst admitting that precipitated copper sulphide (CuS) is a good precipitant in the laboratory, points out that in consequence of its physical condition, and the facility with which it is oxidized to $CuSO_4$, its application in practice is not to be recommended. He recommends fused sub-sulphide of copper (Cu_2S) as a perfect and rapid means of recovering the gold. To facilitate the filtration the Cu_2S is crushed to pass a 60 mesh sieve, and the portion which remains on a 100 mesh sieve only is used; this gives the desiderata of a dry, hard, and granular filter-bed, three points of importance. Whilst charcoal is not free from objections, on account of the large quantity necessary to ensure a complete decomposition of the solution, and the somewhat tedious and troublesome operation of "burning-off" the excess of carbon before smelting the residues, Mr. Vautin claims for this method the advantage that it is not necessary to expel by heat or otherwise any excess of free chlorine from the solution before passing it through the reagent; nor does the presence of any free hydrochloric acid in any way interfere with the reaction. Any copper, calcium, zinc, etc., also passes through, presenting advantages over the use of hydrogen sulphide or ferrous sulphate.

and arsenical pyrites, combinations which do not prevent the application of the process, unless the base-metals, more particularly lead (but always excepting iron), are present in large proportions. Losses are likely to occur through the gold being volatilized or affected in roasting, which is more particularly to be guarded against if copper is present, and the ore be roasted with common salt. Much has been written on this subject, and in fact, enormous losses may occur in the chloridizing roasting of gold ores through volatilization of the gold.*

Mr. Kustel, page 57, records the loss of 20 per cent. of the gold contents in the oxidizing-roasting of certain tellurides of gold and silver, and states it is not a mechanical loss, but is due to volatilization. Though with most ores no loss of gold is suffered in this way during oxidizing-roasting either with iron or arsenical pyrites, loss may occur if the operation be carried on so rapidly that fine particles are carried off by the draught.

A loss of silver in oxidizing-roasting is unavoidable. Plattner † concludes that the percentage increases with the temperature of roasting, and with the looseness or porosity of the roasting charge, that is with the facility with which the air can come into contact with the silver, and the freedom of the silver from combination with other substances. The loss increases also with the time of roasting. He concludes that silver is volatilized as oxide, which decomposes at a lower temperature into silver and oxygen, but Dr. Percy throws doubt on this theory.

In roasting, it is easy to incur an enormous loss of gold by inattention to what may appear insignificant trifles, showing how necessary in such matters is a systematic weighing and sampling, as well as assaying of the ores and products, in order to know at once when such losses are taking place, so as to be able to check them in time. Haphazard and occasional sampling and assaying, are worse than useless; they lead to great losses of valuable capital, frequently to the total abandonment of good properties, and worse than all, to a false sense of self-satisfaction, which discourages investigation and improvement by denying the necessity thereof.

If the gold in the ore is of low fineness or combined with silver, a large part of it may be lost in roasting from a different cause, as the sub-chloride will surround the particles of gold, and prevent any further action of the chlorine upon it, in which case the double process, previously alluded to, must be employed.

The quantity of common salt used in chloridizing-roasting, and the time when it can best be added, are of much importance to the final result;

* "Losses in Roasting Gold Ores and the Volatility of Gold." *Trans. Am. Inst. Min. E.*, vol. xvii., page 3.

† *Metallurgische Rostprozesse*, Freib, 1856.

and they have to be determined by trial, with different ores. The chlorine must be purified from everything that would be likely to cause a reaction between it and the other constituents of the ore.

Other important factors in the general success of the process are :—

1. Close and clean concentration.
2. Amalgamation of any coarse gold, preceding or following the chlorination.
3. Lixiviation of the silver before or after gassing.
4. Absence of any organic matter in the charge, or wash-water.
5. That the ore is crushed properly. A series of experiments should be made to ascertain how coarse the ore should be to give the best results with reference to economy, large capacity, and best extraction. The pulp for the best leaching must be in a granular condition, and carry as small a percentage of dust and slimes as possible. Mr. John E. Rothwell (*New York Mining Journal* of February 7th, 1891) points out that for this purpose rolls, properly managed, are best adapted for this purpose. The chief point is to make the reduction in the size of the particles passed through them gradual. The ore should come to the coarse rolls not larger than $\frac{3}{4}$ inch, and these rolls should crush to about $\frac{3}{8}$ inch. The middle rolls are set about $\frac{3}{16}$ inch or less apart, and the fine rolls about as far apart as the size to which the ore must be crushed. If only two sets of rolls are used, the coarse are set a little closer, and the fine remain the same. The springs should be tight enough in tension, not to give with the hardest ore passing through them, but lax enough to allow a piece of steel or iron to pass through without throwing off the belts. The periphery speed of the rolls should be the same or a little faster than the falling speed of the ore, and the ore should be fed in an even sheet across the surface of the roll. This will keep the surfaces true and produce a granular pulp but carrying a small percentage of dust. A still more gradual reduction can be made by making the rolls of larger diameter and narrower, which will give them also proportionately a greater capacity. Rolls of 39·5 inches diameter and 12 to 15 inches face have been used by Mr. Rothwell with good results.

Dr. T. Egleston writing on the formation of gold nuggets and placer deposits says :—"I have known of gold (Grass Valley, California) being

thrown down on the filter of a Plattner vat by the organic matter contained in the very impure wash-water used for the solution of the gold, rendered soluble by the action of the chlorine. The filter was full of metallic gold, and there was no means of ascertaining how much had been lost. Several ounces of a brown deposit were taken from it, almost pure gold."

An excess of chlorine must be present in the generator, and the ore must be washed and filtered thoroughly, otherwise the tub tails will assay 4 to 5 dollars instead of 75 cents.*

LIXIVIATION.

The MacArthur-Forrest Process for Gold Ores.

This process claims† to extract the gold from pyritic ores, without the necessity of roasting; and in certain cases it may have a considerable field of usefulness. When, for instance, the gold is in an extremely fine state of division, and the ore contains silver as well as gold, the fairly high percentage extracted of each metal may render this method a very desirable one.

For plain gold ores, in which the gold is in fine particles, the barrel-chlorination process seems, however, to give a higher extraction, and with ores of moderate and high-grade appears to work to better advantage.

It would appear, in fact, that the limitations of the cyanide process might be summed up as follows:—

1. That it is only entirely successful with free-milling ores, as although it will deal with pyritic ore, it does so at a greatly enhanced cost.
2. That it is inapplicable to ores containing a considerable percentage of coarse gold.
3. That it cannot be economically applied to rich material, as a loss of 2 dwts. in 8 dwts. ore is a very different matter to a loss of say 2 ozs. in 8 ozs. ore.
4. That it is not applicable to ores containing certain metal and mineral combinations.

On the other hand, it appears to be a process admirably adapted for saving gold in the condition of float, *i.e.* in an extremely minute state of subdivision, which cannot be caught by any process of concentration or amalgamation.

* Phillips, *Trans. Am. Inst. Min. E.*, vol. xvii., page 313.

† *Memoranda on the Treatment of Refractory Gold Ores by the MacArthur-Forrest Process.* Wm. Hodge & Co., Glasgow.

Briefly outlined, the MacArthur-Forrest process originally consisted in pulverizing the ore to 40 or 60 mesh size, and then mixing, and agitating it, with a solution of cyanide of potassium (the ordinary standard strength of which was intended to be $1\frac{1}{5}$ parts of cyanide to 100 parts of water by weight).*

After a sufficient time has elapsed for the solution of the precious metals, the leach is transferred to large wooden filter-tanks, the solutions are allowed to settle, and are drawn off (sometimes assisted by pressure or suction), and the gold and silver contained in these solutions as cyanides, are decomposed and precipitated in a metallic condition, by passing the filtrate through metallic zinc turnings. In the course of this treatment the zinc replaces the gold in solution as cyanide of zinc, which dissolves in the water, while the gold is deposited as a dark powder. This is separated by sieving from the undecomposed zinc, when it is found, by testing with chloride of tin, that the whole of the gold has been precipitated from the leach liquor.

The zinc residues are then removed and dissolved in nitric acid, the gold remaining undissolved as a dark brown powder, which is washed, dried, and melted, yielding almost pure gold.

If there is any silver present it is dissolved with the zinc, and can be recovered by adding a solution of common salt, which throws it down as chloride. It has then to be reduced to the metallic state by contact with sheet-iron or zinc, after which it is washed, dried, and melted.

The chemistry of the process† is simple, depending on the affinity of cyanogen for gold and silver, and the ease with which these metals form soluble double cyanides with the alkali metals. The relative affinities of the different metals, according to Mr. Wm. Jones, stand as follows:—1st gold, 2nd silver, 3rd copper, 4th zinc, lead, arsenic, antimony, etc.

The solvent action on the base-metals can be reduced to a minimum by reducing the strength of the solutions, the readily soluble gold and silver being dissolved out with only traces of copper, zinc, etc.

The best strengths of solutions to use in leaching out the gold from refractory stone depends entirely on the nature of each ore, and it is

* In actual practice, however, these ideas have been modified, and what is known as the percolation system has come into almost universal use, employing standard solutions of a certain strength, first leaching the ore for 6 to 12 hours with 6 to 8 per cent solution, and for 8 to 10 hours more with a weaker liquor, containing 2 to 4 per cent. of cyanide.

† "The MacArthur-Forrest Process for the Treatment of Refractory Gold Ores." *Eng. and Min. Jour.*, New York, 1889, vol. xlviii., page 544.

impossible to lay down any hard-and-fast line. The point must be determined by practical tests.

Filtration of the liquor is accelerated by using a vacuum, and there is no practical difficulty about this, unless there is a large percentage of clayey matter present. The amount of free cyanide in the liquors, after passing through the zinc, is then determined by means of a standard solution of nitrate of silver, and the liquor is thereafter made up to its original strength and used over again.

To extract the gold from refractory ores a number of points must however be observed. If the ore betrays a noted acidity, due to the presence of basic sulphates of iron, etc. (especially marked in the case of disintegrated and weathered sulphides), it should be neutralized with an equivalent quantity of caustic lime in the form of milk of lime. The exact amount of acidity can be determined by shaking up a weighed sample of the ore with water, and adding standard-normal or tenth normal caustic-soda solution till the point of alkalinity is attained, as indicated by litmus or any other suitable tests. The amount of lime is then easily calculated. Some ores show as much as 4 per cent. of acidity in terms of soda, and such ores, on treatment with cyanide solutions without previous treatment with lime, fail to yield their gold contents, whereas when previously treated with lime, the greater part of the gold is easily extracted.

Nearly all sulphides show more or less acidity, but when it is under 0·10 per cent. it may for practical purposes be neglected.

The cyanide solution used should be as free from caustic alkali (NaHO or KHO) as possible, as it is apt to form a sulphide of sodium or potassium with the sulphur of the ores, and thus prevent the gold and silver going into solution. This difficulty, when it does occur, is got over by adding calcium chloride.

The cyanide solutions are best preserved from too great exposure to the air, as a part of the cyanide is apt to be converted by oxidation into the cyanate.

From a chemical point of view it appears, that the economic success of the process, will mainly turn on the price, and consumption of chemicals, and on the time taken in treating large quantities, to extract a given percentage of gold from various combinations of ores in different localities in which the gold exists in a coarse or fine state of division, and in different alloyage, and in which the pyrites is more or less highly concentrated. The ores of the Witwatersrandt seem specially adapted for treatment by this process.

The Russel Process for Silver Ores.

Quoting Mr. C. A. Stetefeldt, on the lixiviation of silver ores, Mr. E. H. Russel, it is said, discovered that a solution of a double salt of cuprous hyposulphite and sodium hyposulphite (formed by mixing sodium hyposulphite with copper sulphate) exert a most energetic dissolving and decomposing action upon metallic silver, silver sulphide, silver minerals belonging to the group of antimonial and arsenical sulphides, and other silver combinations. Hence, if a charge of roasted ore is first lixiviated with ordinary sodium hyposulphite solution to dissolve the silver chloride, and subsequently with cuprous hyposulphite (this solvent is called the extra solution) an additional amount of silver is extracted, which would have been lost in the tailings, by working according to the old method alone. Or, if the roasted ore contain caustic lime and be treated with the extra solution, the deleterious influence of the caustic lime is thereby neutralized. In the same way the extra solution may be applied to extract silver from raw ores without previous chloridizing-roasting, or to lixiviate ores after they have been subjected to an oxidizing-roasting. Mr. Russel also discovered that lead can be completely separated from a sodium hyposulphite solution, as lead carbonate, by sodium carbonate, without precipitating copper or silver.

After decanting the solution from the lead carbonate, silver and copper are obtained from it in the usual way. This method of separating lead prohibits the use of calcium polysulphide as a precipitant for the sulphides, because calcium, entering the regenerated lixiviation-solutions, would also be precipitated as a carbonate with the lead, by sodium carbonate; hence sodium sulphide must be employed. A full investigation has demonstrated that this is by no means detrimental, as sodium sulphide and sodium hyposulphite are more advantageously used in the lixiviation process than the corresponding calcium salts.

Finally, Mr. Russel found that if a hyposulphite solution has a caustic reaction, produced by caustic soda or lime, its solvent power for silver is materially deteriorated. This defect he corrects by neutralizing such a solution with sulphuric acid.

The Van Patera Process (Ordinary Lixiviation).

This process consists in:—(1) Crushing the ore (generally with rolls). (2) Drying the ore. (3) Roasting with salt. (4) Leaching out the base-metals with hot or cold water.* (5) Leaching out the silver with

* The base-metal chlorides in the water may carry off 0·5 to 3 per cent. of silver, but this can be recovered by simple dilution, unless chlorides of lead and antimony be present (which are likewise precipitated), in which case either the ore must be leached from below, under slight pressure, or the silver must be precipitated in troughs outside the tubs.

hyposulphite of soda. (6) Precipitating the silver. (7) Roasting the sulphide of silver and melting to bullion.

It is capable of saving about 85 per cent. of the silver in the chloridized ore, assuming it to be suited to this class of treatment.

The writer will not stop to refer to other wet methods, such as the Claudet and the Kiss, for gold and silver ores, and the Augustine and Ziervogel, used for the treatment of argentiferous copper matte, though they all undoubtedly possess special features of interest.

The difference between the Russel process and ordinary lixiviation, must however be alluded to.

1. It requires a less careful chloridizing-roasting, and on that account a lower percentage of common salt may be used in roasting.
2. It extracts a higher percentage of silver by means of the extra solution. This is specially of importance in treating raw ores, and in lixiviating roasted ores containing caustic lime.
3. It produces sulphides free from lead.
4. It yields lead in the form of lead carbonate as a valuable bye-product.
5. It overcomes the deleterious effect of a caustic lixiviation-solution, by neutralizing it with sulphuric acid.
6. It uses sodium hyposulphite and sulphide exclusively, and not the corresponding calcium salts.

Ores suitable for Treatment by the Russel Process.—It is claimed by Mr. Stetefeldt that almost all silver ores that do not carry a large percentage of lead or copper, can be treated by lixiviation with success and economy. He says :—" I do not mean to create the impression that, from ores containing more or less lead and copper, a high percentage of the silver cannot be extracted by this process. Such ores, however, will in most localities be reduced to better advantage by smelting."

It is safe to state that all ores fit for amalgamation can also be treated by lixiviation, and that the Russel process may succeed where amalgamation is a failure. In cases where lead-bearing silver ores are suitable for concentration, it may be profitable to concentrate the ore by the Krom dry system, obtaining and smelting product, high in lead, and to lixiviate after roasting the tailings and the dust.

The dry system of concentration deserves the preference, because it delivers the tailings and the dust in a condition ready for chloridizing-roasting. In wet concentration, the drying of the tailings would be expensive, and there would be a considerable loss of silver in slimes.

charged for at so much per unit, in excess of a certain percentage fixed by the smelter; 5 per cent. more zinc being commonly allowed in oxidized than in sulphuretted ores.

When the ore is calcareous, or highly charged with oxide of iron, a rebate on the ordinary public tariff-price, which represents their maximum charges, is often allowed by smelters. As regards the lead, some smelters require a certain minimum, and an extra charge is made for each per cent. of lead below it; as a rule, no payment is made when the assay shows less than 10 per cent.

It is usual to deduct 5 per cent. for loss of silver in the ore, and calculate the value on New York quotations for the balance; when, however, the ores are dry or siliceous, a still further deduction is made, often as high as 10 per cent. for 100 ounces ore, but less for higher grades.

The gold is paid for from $\frac{1}{10}$th of an ounce per ton upwards, at the rate of £3 15s. to £3 19s. 2d. per ounce. New York quotations for silver and lead on the day of settlement, are assumed as the basis of price.

(*To be continued.*)

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE ROYAL VICTORIA HOTEL, SHEFFIELD, NOVEMBER 26TH, 1892.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members, having been previously nominated :—

MEMBERS—

Mr. WALTER HARGREAVES, Colliery Manager, Robin Hood Collieries, Wakefield.

Mr. ROSLYN HOLIDAY, Mining Student, Ackton Hall Colliery, Featherstone, Pontefract

The PRESIDENT, in accordance with the notice given at last meeting, proposed that Mr. Goodman, the Professor of Engineering at the Yorkshire College, should be an Honorary Member of the Institute. He also thought they ought to make the Professor of Mining at the Yorkshire College and the Professors of the Firth College Honorary Members of that Institute.

The motion was carried unanimously.

Mr. JEFFERSON read the following paper on "The Wear and Tear of Steam Boilers due to Expansion and Contraction-Strains" :—

THE WEAR AND TEAR OF STEAM BOILERS DUE TO EXPANSION AND CONTRACTION-STRAINS.

By J. CLARK JEFFERSON.

Connexion Between Change or Difference of Temperature, Expansion and Contraction, and the Tensile and Compressive Strains Produced Thereby.

If a piece of iron 800 inches long at 32 degs. Fahr. is heated to 212 degs., it becomes 801 inches long at the latter temperature if perfectly free to elongate. The elongation of iron or steel is thus $\frac{1}{800}$ for a difference of 180 degs.; or $\frac{1}{144000}$ for 1 deg. Fahr.

If a piece of iron 1 square inch in sectional area and 30,000,000 inches long could be obtained, and supported so as to be capable of elongation or contraction without friction, a pull of 1 lb. would make its length 30,000,001 inches and a thrust of 1 lb. would make its length 29,999,999 inches. In other words the elongation or contraction would be $\frac{1}{30000000}$ of the length for a force of 1 lb.

From the above fractional elongations or contractions, viz., $\frac{1}{144000}$ for 1 deg. Fahr. rise or fall of temperature, and $\frac{1}{30000000}$ for a pull or thrust of 1 lb., it follows that a rise or fall of 1 deg. Fahr. in temperature produces the same elongation or contraction as a pull or thrust of 208·3 lbs. (say 200 lbs) per square inch. If a piece of iron therefore were rigidly held so as to prevent its elongation or contraction, a rise or fall in temperature of 1 deg. Fahr. would set up a tensile or compressive force of 200 lbs. per square inch.

Though this condition of absolute rigidity does not obtain in steam boilers, the above figure may be taken to represent the reserve force available to produce distortion or fracture of parts of a boiler. A rise or fall of 2 degs. Fahr. in temperature would represent a possible strain of 400 lbs. per square inch, 3 degs. Fahr. of 600 lbs. per square inch, and so on. Taking the tensile strength of iron boiler-plates at 22 tons per square inch and of steel boiler-plates at 30 tons per square inch, it will be seen that a fall of 250 degs. Fahr. in temperature in the case of iron, and 340 degs. Fahr. in the case of steel, would produce rupture were the ends of a plate held rigidly fast. Such a rupture would be very readily brought about if the crown-plates of a boiler were allowed to

become red hot through shortness of water and if the cold-feed supply were suddenly turned on. It is to this cause, and not to the sudden generation of steam, that the liability to explosion under the above-mentioned condition should be attributed.

The above considerations will make clear the necessity of annealing boiler-plates after they have been rolled, or of ensuring that the cooling down takes place slowly and uniformly; otherwise there may be initial strains in the plates even before they are used in the construction of a boiler, leading to failure, or cracking of the plate under working conditions. On this account also great care should be observed in the flanging of boiler-plates.

Temperature at Various Parts of Steam Boilers.

In the case of the ordinary Lancashire or Cornish boiler the temperature just above the fire may be estimated under ordinary conditions at 2,350 degs. Fahr., though where the draught is very carefully regulated, it may reach 2,700 degs. Fahr. The temperature falls at first very rapidly, and then, as the distance from the fire-bridge further increases, much more slowly. Without entering into the question of the distribution of heat in the flues of a steam boiler, it will be sufficient to assume that the average temperature of the furnace-gases in the first half of the internal flues is 2,350 degs. Fahr., in the second half 1,800 degs. Fahr.; in the first half of the middle flue 1,450 degs. Fahr., and 1,150 degs. Fahr. in the second half; in the first half of the side flues 900 degs. Fahr., and 670 degs. Fahr. in the second half. The temperature of the water in the boiler may be estimated at 350 degs. Fahr. The difference of temperature on the two sides of the plates at the parts of a boiler named above would therefore be respectively 2,000 degs., 1,450 degs., 1,100 degs., 800 degs., 550 degs., and 320 degs. Fahr.

This paper is not concerned, however, so much with the temperature of the gases as with the temperature of the plates; or, to be precise, with the average temperature across the thickness of the plate. No data have been published as to the actual temperature of the plates. The temperature of the water in the boiler may be estimated at 300 to 350 degs. Fahr., when the boiler has been at work some time. Lead plugs fuse at about 600 degs. Fahr., and iron at dull red heat in the dark has a temperature of 750 degs. Fahr. It will be evident therefore that under ordinary conditions the temperature of the plates must be considerably under 600 degs. Fahr., even over the furnaces. The temperature of iron plates, with water on one side and exposed on the opposite side to so

high a temperature as 2,300 degs. Fahr., does not rise to anything like a mean between the two owing to the high conducting power of iron. It will probably not be far wrong to assume the temperature of the plates over the furnace at 450 degs. Fahr., and that of the external side flues at 380 degs. Fahr.

Where furnace tubes or the plates generally are connected with lap joints, the condition is very greatly altered. The transmission of heat through a plate depends more on the conducting or transmitting power of the surface of the plate, or on external conduction, than on the internal conduction. The internal conducting power of copper compared with that of iron is as 12 to 5, and yet the evaporative efficiency in the most favourable case is only 20 per cent. greater for copper, and in practice there is no apparent difference in the evaporative efficiency in iron plates of $\frac{3}{8}$ inch and $\frac{1}{2}$ inch thickness. The excess temperature above that of the water may therefore be considered at least twice as great in the case of the outer of two pieces of iron in a lap joint.

Some approximation can, however, indirectly be arrived at as to the average difference in temperature between the upper half of the furnace flues and that of the shell-plates in the side and bottom flues. In the case of a 24 feet boiler, with the gusset stays properly designed to take the strain due to the pressure of the steam on the ends of the boiler, the elongation of the upper part of the internal furnace-tubes is found to be about $\frac{3}{16}$ inch. This is a fractional elongation of $\frac{1}{1536}$ and dividing this by $\frac{1}{144000}$ (the fractional elongation for 1 deg. Fahr.), we obtain 94 degs. Fahr. as the excess temperature of the furnace-tubes above the shell-plates, and 94 × 208 lbs. = 19,552 lbs. or very nearly 9 tons per square inch of thrust. Taking only the upper half of the furnace-flues as effective, and their diameter at 33 inches and thickness at $\frac{3}{8}$ inch, an available end thrust of 340 tons is obtained, due to the expansion of the internal flues. As the end plates bulge out long before this pressure is reached, only a fraction of this force is actually brought into play.

To understand more clearly the influence of this expansion on the wear and tear of a boiler it will be advisable to consider a little more closely the distribution of heat in the internal flues. Immediately over the fire the temperature is greatest ; whilst below the firebars, the plates being exposed to the cold air entering and shielded against the radiation from the fire by the firebars, the temperature is least. Beyond the fire-bridge not only is the temperature of the gases lowered, but the bottom plates being exposed to the heated gases, the difference of temperature between the top and bottom plates is much less than in front of the fire-

bridge. The distance, therefore, which the top of the last plate of the flue expands beyond the bottom of the plate is much less than at the front end (Fig. 1, Plate XIV.); and consequently the grooving of the back-end plate is much less frequent nor is it so great as at the front-end. This grooving is the result of the repeated bending of the end plate over the flue angle-iron caused when the internal flues expand and contract, and extends more or less over the end plates at the parts indicated by the hatched areas, *a a*, Fig. 2, Plate XIV. The nature of this action is very similar to the gradual fracture of a piece of sheet-metal by repeated bending backwards and forwards. In Figs. 3 and 4, Plate XIV., the length of the internal flues is supposed to be exactly equal to the length of the shell, the end plate *a* being straight before expansion begins. Fig. 4 is intended to represent (not to scale) the position of the flue angle-iron, and to show the bending of the end plate after expansion has taken place. The end plate *a* is bent at *b* and *c*, but owing to the bending strain being distributed over a larger section or curve at *c* than at *b*, and the rivets—closer together at *b* than at *c*—holding the plate more rigidly at the flue angle-iron, the strain per unit of section at *c* is much less than at *b* and the bending at *c* takes place with a curve of greater radius. Following the analogy of the breakage of a piece of iron by repeated bendings, it might be supposed that the grooving or fracture should commence at the outside of the bend, *i.e.*, the outside of the end plate over the flue angle-iron. The grooving, however, is always found on the water side. The explanation of this fact is most probably to be found in the crushing effect of the edge of the angle-iron against the inside of the plate, disturbing the surface of the plate; which is thus more readily attacked by the corrosive action of water under considerable pressure. But for the presence of water the bending effect would show itself as a crack of comparatively very small width. The grooving here referred to is always exhibited as a well-defined groove, which appears as if the iron had been eaten or corroded away. There is, however, little doubt that this grooving is the result of two actions, a fretting or mechanical action due directly to the bending movement which disintegrates the metal, and the corrosive action of the water in the boiler under considerable pressure.

In many cases the internal flues of a boiler are purposely made $\frac{3}{16}$ to $\frac{1}{4}$ inch shorter than the shell, so as to allow for the expansion of the internal flues. Figs. 5 and 6, Plate XIV., illustrates this practice, the dotted lines showing the positions after expansion. In this case it will be seen that the bending at *b* is first produced when the end plate and flue angle-iron are drawn together in riveting up, and the grooving very naturally appears on the outside of the bend at *b*.

Where the scantling of the flue angle-iron is somewhat weak compared with the end plate, the grooving is found to take place at the root of the angle-iron. Grooving at the root of the angle-iron is most usually found in the case represented by Figs. 5 and 6, Plate XIV., where the internal flues in the first instance are made too short; the first incipient fracture being due to the riveting up, which tends to open the angle-iron. The angle-iron requires to be made thicker, as the fibre of the angle-iron runs crossways with the direction of the strain.

In Figs. 3, 4, 5, and 6, Plate XIV., the bending of the end plate is represented as commencing at the termination of the gusset stay at *c*, and it will be evident that the angle of the bend at *b* is the greater, the shorter the length of *b c*. To avoid grooving, the distance *b c* should never be less than 7 inches, and as soon as there are any signs of grooving it is desirable to take out the bottom pairs of gusset-rivets in the end plate, so as to give more freedom to the end plate in bending round the flue angle-iron.

The effect of frequent and rapid changes of temperature, produced every time the fire-hole door is opened, frequently evinces itself in leakages of the rivets of the fire-box, especially in the circular seam, where lap-joints are used. When the lap is heated the rivet-hole tends to become smaller and the rivet larger in diameter (Fig. 7, Plate XIV.) and the metal, if the hole and rivet are a perfect fit when cold, is compressed, so that when it cools down the hole is slightly larger and the rivet slightly smaller than at first. So long as the ordinary working temperature is not exceeded, the space between the rivet and the rivet-hole always closes up tight when the boiler is at work, and is tight when cold and the pressure down. But, if at any time the ordinary working temperature is considerably exceeded, the compression of the metal may be so great, that the space between the rivet and rivet-hole is not closed tight at the ordinary working temperature, and the rivet-hole leaks.

But when heated, a rivet not only expands in diameter, but also longitudinally (Fig. 8, Plate XIV.), and if while so heated a current of cold air impinges on the exposed and comparatively large surface of the rivet-head, this tends to cool down more rapidly than the plate underneath and partially protected by the head, and this end of the rivet takes a slight permanent set or elongation; if the temperature has been excessive, or this sudden cooling is frequently repeated, the rivet may thus become slack and lead to leakage.

In one or both of the two ways just described is to be found the cause for the frequent leakage of rivets slightly above the level of the

grate-bars on the sides of fire-boxes; but there is also another manner in which the seams of a fire-box are strained. Owing to the great difference of temperature between the top and bottom of the fire-box, the seam at the bottom is subject to a longitudinal tensional strain and at the top to an equal compressive strain. If the plate is excessively heated, this may lead to elongation of the rivet-holes in the fire-side lap of the upper half, as shown in Fig. 9, Plate XIV.

In Fig. 10, Plate XIV., if a and b represent internal and external rings fitting each other perfectly, and the inner one a is heated while the outer ring b is kept cool with water, the inner ring a can only expand by becoming thicker, or by stretching the outer ring b. If the difference of temperature has been sufficiently great, the outer ring b may be permanently stretched, or the inner ring a permanently compressed or made thicker. In the case of the lap-seams of boiler furnaces where both the inner and outer rings are of equal thickness, an excessive temperature generally causes the inner lap to be compressed or made thicker, and on cooling the ring contracts to a less diameter than it originally had and the seam may leak. For example, in Fig. 11, Plate XIV., if the dotted line represents the thickening of the inner lap of a circular seam when excessively heated, and a draught of cold air suddenly impinges on the inner lap, the parts not protected by the rivet-heads will suddenly contract before the outside lap; this contraction will tend to take place with the contraction of the arc $b\ b'$, and not with the contraction of the arc $a\ a'$, as the mean circumference. But this contraction of the inner lap being resisted by the outer lap, which is not subject to the sudden cooling, sets up a tensional strain in the inner lap; and the section from the rivet-hole to the lap being the smallest often fractures (Fig. 12). These rivet-hole-to-lap-edge fractures are, however, often started in the construction of a boiler when the rivet-holes are punched or even drilled and a drift is used where the rivet-holes of a lap-joint are not exactly opposite.

In the case of lap-joints in the shell, say in a middle flue, or in the case of externally fired boilers, when the difference of temperature is considerable the outer lap tending to expand and held close to the inner lap by the rivets, expands in the manner indicated in Fig. 13, Plate XIV. If in Fig. 14, Plate XIV., R represent the radius of the outside lap before being thus heated, R^1 the radius after being heated; P the mean pitch of the rivet-hole corresponding to R; P^1 the mean pitch corresponding to R^1; r the difference between R^1 and R; and p the difference between P^1 and P; then $r : p :: R : P$. If the boiler be 7 feet in diameter

and the pitch of the rivet be 2 inches, then the distance which the outer lap tends to move away from the inner lap is 21 times the expansion of the pitch. As the length of the rivet is very much shorter than the pitch, and only the outer half of the rivet partakes of the excessive rise of temperature, it will be evident that the elongation of the rivet is much smaller than that of the pitch, and consequently it is excessively less than the distance r, probably less than $\frac{r}{100}$. When the outer lap cools, the plate between two rivets tends to contract in the form which it has assumed, that is not with the centre of the boiler as a centre, but with the centre of the arc a as a centre; so that when the outer lap again assumes the temperature of the inner lap, the seam may gape in the centre between two rivets (Fig. 13).

The last two paragraphs make it clear, how it is that the leakages of the internal flues are more generally found at the rivets, and in the external flues between the rivets; and also how it is that the seams exposed to the furnace in internally fired boilers are less liable to leak than those of externally fired boilers; apart from the fact that in the latter case, there is a great liability of sludge settling over the furnace-plates, which baking fast on them, prevents the water from keeping the joints sufficiently cool.

In the case of vertical and locomotive boilers where the fire-box and the outer shell are connected together at the bottom by a thick base ring, the expansion of the fire-box usually tends to take place in a downward direction, for the same reasons that in a Lancashire or Cornish boiler the expansion of the internal flues usually takes effect at the front rather than at the back-end. In vertical and locomotive boilers, in consequence of this downward expansion of the fire-box, the base ring is thrust downwards and outwards as indicated in Fig. 15, Plate XIV. This produces a bending and grooving action at both a and b, but as will be evident, it is most severe at b. This grooving is almost invariably found in vertical boilers, and requires to be very carefully watched. Explosions have occurred in which the outer shell has thus been torn away from the base ring. The expansion of the fire-box of vertical boilers is often partially accommodated by the bending of the crown, especially where the fire-box is of considerable height, as shown by the dark lines in Fig. 15, Plate XIV. In other cases, the compressive strain produced by the expansion is found to groove the uptake above the top edge of the angle-iron ring at y, or the crown of the fire-box round the ring at x. The grooving at x is further promoted by the tendency of the uptake hole in

the crown of the fire-box to contract, and of the uptake and angle-iron ring to expand. The grooving at x is usually found to be considerably broader than at y. The expansion of the fire-box downwards often produces leakage of the rivets round the fire-hole ring, and in the case of locomotive boilers tends to bend downward on the inside of the fire-box sheet-stays, and draw them up again when cold. These are sometimes in consequence broken. Not only does the expansion act downwards, but it also tends to increase the length and width of the fire-box as shown in Figs. 16 and 17, Plate XIV. This expansion acts by forcing outwards and bending the corners, and owing also to the expansion of the tubes which tend to bulge out the tube-plate, this bending action is most severe on the flanges of the tube-plate, which sometimes crack in a vertical line on the bend of the flange. This action frequently evinces itself by leakage of the lap-seam towards the lower part of the fire-box. The top row of stays in the tube-plate should not be brought too near the tube-holes, otherwise the bending takes place too quickly. Owing to the reduced section across the tube-holes, this bending usually occurs chiefly about the third or fourth row of tubes from the bottom. If, in order to illustrate this more clearly, an exaggerated inclination is shown in Fig. 18, Plate XIV., it will be seen that either the hole or the tube must be compressed as indicated by the dark parts c; and, when the tube-plate cools and resumes its original position, the tube and plate will only be in contact at the inner and outer edges of the tube-plate hole (Fig. 19, Plate XIV.). In time the tube-plate takes a permanent set, and unless the tubes are expanded to suit, they leak. It will be noticed also that the resistance of the tubes to the bending of the plate causes the tube to act as a lever, tending to prize the plate above the hole away from the portion below; this pressure acting over a row of holes tends to, and often does, split the tube-plate along the centre-line across the holes.

Fig. 20, Plate XIV., illustrates the effect of excessive heat on the sides of a stayed fire-box. The side of the plate next the fire being more highly heated tends to expand most, and to accommodate this the plate between the rivets tends to bulge out towards the fire. This action is assisted by high steam-pressure, and where the water-side is allowed to become encrusted, this bulging or papping is often very considerable.

In the working of Lancashire and Cornish boilers it is desirable that the draught should be carried round the flues in a particular direction. For Lancashire boilers this direction is from the internal flues down to the middle flue, along this to the front, and then splitting to the side flues

and to pass through these to the chimney. If the draught were carried to the side flues first, and then back by the middle flue, the plates over the latter would be much cooler; and consequently, the expansion of the plates in the bottom of the shell being much less than that of the internal flues and the side flue-plates, the bottom plates of the shell would have a considerable tensional strain in addition to having to carry part of the steam pressure on the ends, and the seams in the middle flue might be strained so much as to cause them to leak, especially near the seating-walls.

In the case of Cornish boilers, owing to the proximity of the bottom shell-plates to the bottom plates of the internal flues, the most desirable direction is the reverse of that desirable in the case of Lancashire boilers. That is, for Cornish boilers the draught should go along the side flues to the front end, then unite to the middle flue and pass along it to the chimney. If the draught were carried directly to the middle flue the bottom flue-plates would be heated much more than the plates at the bottom of the internal flue, especially where the water is muddy; and these plates being so close together, a great tensional strain would be set up at the circular seams in the bottom of the internal flue, and might lead to leakage. Moreover, as the difference of temperature of the bottom flue-plates and the side flue-plates is much greater than if the draught were carried as above described; owing to the side-heating efficiency being less than the top-heating efficiency in the middle flue; the difference between the expansion of the side flue-plates and the middle flue-plates would be correspondingly greater; and the side shell-plate joints, in addition to having to take their share of the steam pressure, would have to support the expansive thrust of the bottom flue-plates and might leak. This leakage usually occurs at the circular seams, slightly above the seating-walls and towards the middle of the boiler.

The above effects would be exaggerated where the attempt is made to get up steam too quickly or to cool the boiler down too rapidly. If this is attempted in the case of Lancashire boilers fired the proper way, it tends to cause leakage at the bottom of the internal flues, especially below the fire and the side flues. In the case of Cornish boilers it would tend to cause leakage of the seams in the bottom of the middle flue and the internal flues.

The principal lesson to be learnt from the points referred to in this paper is the importance of keeping the working temperature for any part of the boiler constant for that part.

The PRESIDENT thought it was their duty before any discussion took place to pass a hearty vote of thanks to Mr. Jefferson for his valuable paper. He did not remember one which combined more scientific knowledge and practical information. Mining engineers in putting down new plants required information as to the construction of boilers, and a paper like the present would help them very much. Formerly boilers were thought best and safest when 7 feet in diameter, but he thought after what had been said and from recent experience that less wear and tear took place with those of larger diameters. If they showed the boiler-maker they understood something about using a boiler, keeping an uniform temperature, and preventing unequal strains, they would be able to point out to him that many of the repairs they had to make and pay for were due to bad construction. In the case of manufactories where steam was regularly required they had less unequal strains, but the boiler at a colliery might be working at a certain pressure one hour, and the next be blowing off steam, therefore such a boiler was subject to very unequal strains. He had great pleasure in moving a vote of thanks.

Mr. SOUTHALL, in seconding the motion, said it was very desirable that colliery managers should obtain all possible information regarding the use of boilers. Gentlemen who took up certain points in connexion with machinery and boilers and made these their whole study were much more able to deal with those points than many of them who had their time taken up with the whole management of collieries.

The motion was carried unanimously.

Mr. JEFFERSON said that as to the best size of boiler, until a few years ago 7 feet was considered the most desirable size, but the present tendency was decidedly to increase the diameter of the boiler. One or two had recently been made under the inspection of the Boiler Insurance Company which he was connected with for the Leeds Corporation, and these were 9 feet 6 inches and 10 feet in diameter. They were heated by Horsfall destructors. With regard to the general question as to the best boiler for mill or colliery purposes, the first consideration was that the larger the boiler the greater the steam capacity, and the less need to fire the boiler hard in order to get up steam ; another consideration was that the first expense for a given power was smaller with a large boiler. Then again, with large boilers the junctions with the curves can be made of larger radius compared with the thickness of the plates than in the case of small boilers and the general temperature for any given distance across the plates will be lower in the case of large boilers than in the case of small ones. The

efficiency of the fire-grate is somewhat greater for large boilers than small ones. There was a certain amount of dead space taken up in a fire-grate, and as they could only get them of a certain size it followed that the bigger the fire-grate the greater the efficiency. The practice now was to make boilers 8 or 9 feet in diameter, and there were no difficulties in making them, as makers were well provided with tools for dealing with the larger plates.

Mr. ANDREWS expressed the great pleasure he had had in listening to this most valuable and practical paper. Theoretical mechanicians used to regard boilers as a thin line with fire on one side and water on the other, but when they came to practical engineering a different state of things prevailed. He had had himself much pleasurable profit in studying the effects of temperature on various metals, and had a fellow-feeling with Mr. Jefferson in the researches he had made. One or two points struck him in connexion with the paper as to the reason of the plates cracking. In addition to the causes mentioned by Mr. Jefferson, which were really the principal causes of breakage and fracture of boiler-plates, another fact, he thought, had a bearing on the question. Six or seven years ago he made a number of experiments on a large scale to determine the relative expansion of metals from very low temperatures, taking the whole series of modern metals, Bessemer steel of low and high carbon, Siemens-Martin steel, soft and hard crucible steel, and various other metals. The research he was engaged on then was to ascertain the effect of temperature on railway axles. He came on a fact which astonished him and threw light on the subject of the disintegration of metallic structures by expansion. He found an unequal expansion of a metallic forging in the direction of the length and across the diameter. He might in a few words give the results of those observations as contained in his paper communicated to the Royal Society in 1887.* The metals he observed were "large forgings" of different metals, 7 feet 3 inches in length and 5 inches in diameter. These were planed perfectly square at the ends, turned, and polished bright.

"The range of temperature chosen for the observations was from 45 degs. C. to 300 degs. C.

The experiments were conducted as follows:—For the measurements commencing at the low temperature of 45 degs. C., the bars (having previously been slowly reduced to the temperature of 0 degs. C., and then gradually cooled to 18 degs. C.), were placed upright in the bath A, and immersed in a freezing mixture of

* *Proc. Royal Society*, 1888, vol. xliii., page 301.

three parts of calcium chloride, and two parts of snow, each of these ingredients previous to mixing being maintained in separate jacketed freezing tanks at a temperature of 18 degs. C. The vessel A, containing the bars and the calcium chloride freezing mixture, was further surrounded by another compartment holding a quantity of a freezing mixture of snow and salt at a temperature of 20 degs. C. By this means, and by constantly renewing the calcium chloride and snow mixture during the experiments, a uniform temperature of 45 degs. C., as registered by an alcohol thermometer, was maintained for the experiments in the cold bath A.

Much larger cooling tanks of a snow capacity for each charge of 8 cwts. were used for the large forgings, and a large cast-metal oil-bath having a capacity of about 70 gallons of oil was used for the highest temperature.

The bars remained thus immersed in the freezing bath whilst their internal temperature was regularly ascertained by another alcohol thermometer placed in a hole in the centre of the test bar C, wherein was also placed a little alcohol.

When the bars had reached and remained for some time at the registered temperature of 45 degs. C., each was in turn removed and placed on a suitable wooden frame, and its length instantly and carefully measured by telescopic readings from a delicate micro-vernier gauge (deviations of $\frac{1}{5000}$ of an inch were perceptible) also supported on a suitable rigid stand. The bars were then replaced for a short time in the foregoing mixture and again removed, and their diameter then carefully measured. No perceptible alteration in the temperature of the bars occurred during the very short time occupied in taking the observations, and frequent tests were made to ascertain this. The average of about thirty measurements in each case, both longitudinal and transverse, was regarded as fairly accurate. The dimensions of the bars were taken in a similar manner for the temperature from 18 degs. C., substituting in another cold bath, B, a freezing mixture of snow and salt to obtain this temperature, and using powdered ice and snow for the observations at 0 degs. C. The higher temperature observations were obtained by heating the whole of the bars in a large hot-water bath for the period necessary to ensure that their temperature throughout was as required, and the oil-bath was used for the temperature of 300 degs. C. Liability to temperature errors was, as far as possible, carefully guarded against by constant reference and comparison between the bath thermometers and that in the centre of the test bar, and by keeping the bars immersed during sufficiently long periods.

The hammered metals under observation were large forgings of the different metals 7 feet 3 inches long and 5 inches diameter, planed perfectly square at the ends and turned and polished bright. The measurements were taken on the total length of the forgings, as in the case of the rolled metals, to ensure greater accuracy, the experiments being conducted in somewhat similar manner; but owing to the greater length of the forgings a modification of the method was made. One end of the forging was rigidly secured and the expansion ascertained by measuring the diminishing space between the other end of the forging and a fixed point situated a distance from it. The results are recorded on Table II. It is interesting to notice that the coefficients of dilatation were greater in the case of the 'soft' than the 'hard' steels, a circumstance which may be accounted for by a reference to the table of the analyses, from which it will be seen that the percentage of combined carbon was much lower in the 'soft' than in the 'hard' steels; the percentage

of pure iron was consequently also greater in the 'soft' steels, this caused them to be of a greater specific gravity. The results appear also to indicate another circumstance of metallurgical interest, viz., that the dilatation was generally rather more in the direction of the length of the metallic cylinders than when measured across the diameter—numerous repeated experiments confirmed this. The result appears more marked in the large round forgings of hammered steels and wrought iron than in the case of the rolled bars. It would therefore seem probable that the crystalline particles of the metals suffer slight permanent alteration of form in the direction of their length during the process of rolling or drawing out, sufficient to very slightly affect their relative longitudinal and transverse dilatations.

Furthermore, the observations of this memoir, conducted at these very low temperatures, experimentally confirm the suggestion of Professor Tait, inasmuch as the coefficients of dilatation were found generally to decrease with the reduced temperature below 0 degs. C. The author also found such to be the case in his observations on the 'Heat Dilatation of pure Ice from very low Temperatures.' (See *Proc. Royal Society*, June, 1886, No. 245, page 544.)

It may be remarked that many tons of the various freezing mixtures, snow, etc., were required for the experiments."

The PRESIDENT asked whether the fracture of the iron at a very low temperature had a similar appearance to an overstrained piece of iron?

Mr. ANDREWS—Yes.

The PRESIDENT—Because many years ago Fairbairn conducted experiments to show the effect of snow on iron, and found that the fractures had a crystalline appearance They wanted to know the effect of cold in connexion with colliery work, especially considering the exposed position of the headgear and pulleys. Certainly they were heated when the pulley revolved, but they should be made of an increased diameter to compensate for the effects of cold.

Mr. ANDREWS said that would be so. He found, speaking roughly, that the resistance of metals to impact at low temperature was greatly reduced as compared with the resistance at higher temperatures. He carried these down to zero Fahr., using freezing mixtures to reach that temperature. He might refer to a few results recently communicated to the Institution of Civil Engineers.*

"A great number of railway axles of the same kind were tested for strength at different temperatures (212, 120, 100, 10 to 7, and 0 degs. Fahr.). Each axle received the desired temperature by being left a sufficient length of time in a water-bath or freezing mixture. It was then laid horizontally on two supports, and a weight w (1 ton) was allowed to fall freely on the centre of the axle from a height h ($2\frac{1}{2}$ to

* *Proc. Inst. C. E.*, 1891, vol. cv., page 161.

To illustrate Mr J. Clark Jefferson's Paper on "The Wear and Tear of Steam Boilers &c."

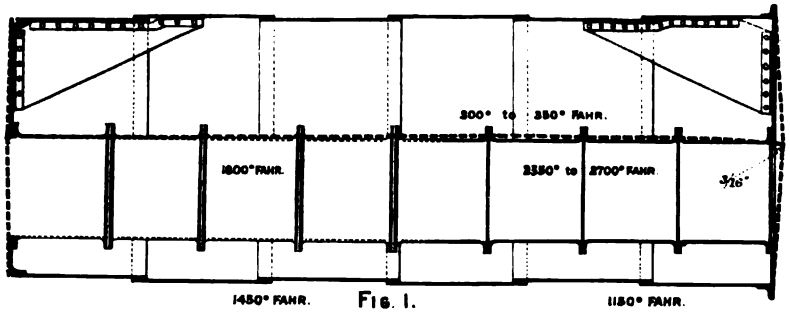


Fig. 1.

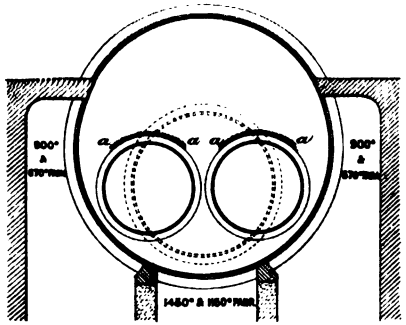


Fig. 2.

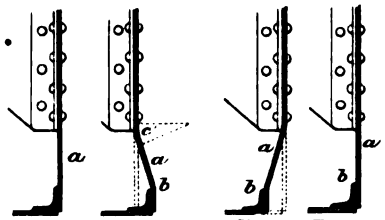


Fig. 3. Fig. 4. Fig. 5. Fig. 6.

Fig. 7.

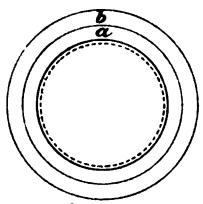


Fig. 10.

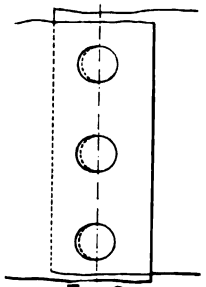


Fig. 9

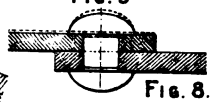


Fig. 8.

Fig. 11.

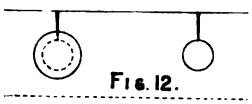


Fig. 12.

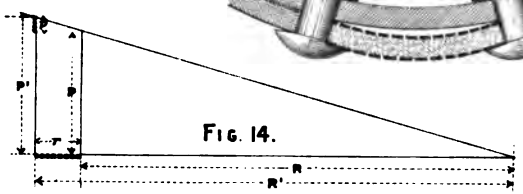


Fig. 14.

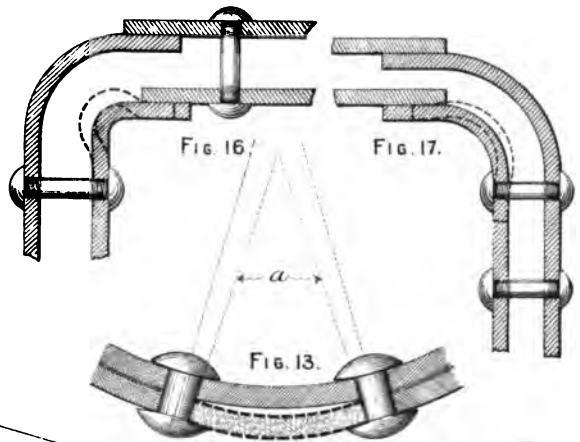


Fig. 16. Fig. 17. Fig. 13.

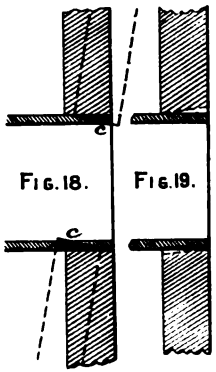


Fig. 18. Fig. 19.

Fig. 20.

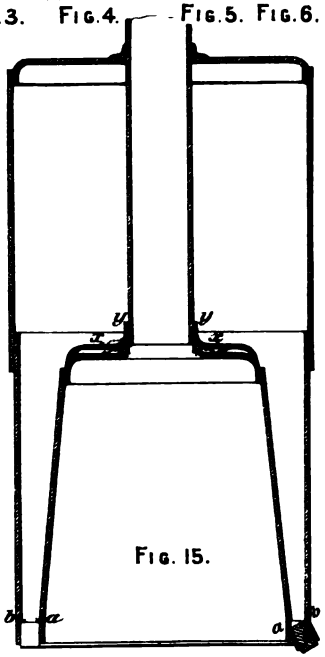


Fig. 15.

15 feet). If x represents the deflection in the centre caused by the blow, then $F = k\,w/x$ is a mean measure of the resistance which the axle presents to bending for the unit of length.

After each blow care was taken that the axle again took the same temperature as before, when it was again placed on the supports with the side which was previously underneath at the top, and again struck with the same force until at last breakage took place. If all the values of F are summed (up to breakage), this gives a measure of the resisting strength. The higher the temperature of the tests the greater was the resisting strength of the axles to the force of the impact, so that the resisting strength to impact decreases with the temperature. The deflection, up to breaking taking place, was the greater as the axles were warmer. The other conditions remaining the same, the mean force was greater with the stronger blows (greater fall) than with the weaker ones. With warm axles the surfaces of the fractures were more fibrous, with cold ones more crystalline in grain.

"The conclusions receive confirmation from the recent experiments made in Sweden by Mr. C. P. Sandberg, Assoc. M. Inst. C.E., showing the effect of low temperature on the strength of wrought iron and steel rails. Mr. Sandberg found that the resistance of steel rails to impact was considerably reduced at low temperatures, and this is also in accord with my experience.

In connexion with the subject reference may be made to the following accidents which have happened during the occurrence of prolonged low temperatures, and afford a practical accentuation of these results, viz.:—

The serious Newark accident in 1869, from the breaking of a steel tire during severe frost.

The following particulars also show the increased breakage of steel rails during the cold season of the year in America. The total number of accidents is compared with that due to broken rails:—

	1885.			1886.		
	Total.	Broken Rails.	Per Cent.	Total.	Broken Rails.	Per Cent.
First quarter ...	273	23	8·4	447	67	15·0
Second quarter ...	234	10	4·3	218	8	3·6
Third quarter ...	341	4	1·2	259	8	3·1
Total ...	848	37	4·4	924	83	9·0

Mr. Wallis, Superintendent of the Grand Trunk Railway of Canada, states:—'I may say, for Mr. Andrews' information, that there is no doubt that the breakage both of axles and tires (all other conditions except that of temperature being equal), is greatly influenced by the severity of the climate in winter.'

On the Grand Trunk Railway during the year 1884, out of a total of fifty-six broken tender and car axles, only twenty-three failed during the summer months, and the remaining thirty-three during the winter season.

Some statistics of the total breakages of tires on German railways in 1887, quoted from Stahl und Eisen, in *The Engineer*, November 9th, 1888, page 387, ascribe 13·74 per cent. of the total breakages to low temperature and change of temperature.

Reference may also be made to the fracture on February 27th, 1889, of a steel tire on one of the driving wheels of the locomotive which caused the train to fall through a bridge at St. George's, Western Ontario, on February 27th, 1889, during the prevalence of low temperature. The breakages of steel tires in Russia are about 50 per cent. more in winter than in summer. Further confirmation is afforded by the following instances, which occurred during the recent severe winter, viz. :—

The fracture of a wagon axle near Blaydon Station, North Eastern Railway, early in December, 1890; atmospheric temperature about 25 degs. Fahr.

The sudden fracture of the Siemens' steel driving axle of the engine of a London passenger train at Kirtle Bridge, near Carlisle, January 8th, 1891; atmospheric temperature at the time about 17 degs. Fahr.

The fracture of the Siemens' steel engine axle of a passenger train at Abington, Caledonian Railway, February 4th, 1891; atmospheric temperature at the time about 34 degs. Fahr.

The fracture of the Siemens' steel axle of a sleeping car on a Western bound express on the Canadian Pacific Railway, near Schreiber, in the Lake Superior section of the line, which produced such calamitous results on February 5th, 1891; atmospheric temperature at the time of the accident about 10 degs. Fahr.

Reference has already been made in the former part of the research to the extent to which increased rigidity of the permanent way during frost probably influences the breakage on railways. The whole of the experiments concur in substantially demonstrating that the resistance of railway axles to impact and concussion, etc., is materially reduced when the metal is at a low temperature; and these experimental results are in accord with practical experience.

Some idea of the difficulties and extent of the investigation is afforded when it is stated that a total number of about 286 railway axles and forgings, weighing 41 tons 16 cwts., have been tested and destroyed in the various experiments, and about 273 tons of snow, ice, and salt, have been used for the freezing mixtures required."

It occurred to him that a force of disintegration was at work in boilers in addition to those mentioned by Mr. Jefferson, namely, the unequal expansion of metals. They could understand that with the crystal of metal expanding equally in all directions if it contracted equally no great harm would be done, but if it expanded unequally constant expansion would produce disintegration and ultimate fracture. Another remark he should like to make on the grooving of the plates. The unequal expansion of metals involved, first, expansion, and in another case, which he had been investigating, corrosion of the plates. He was just finding out that the corrosion of metals was considerably influenced by physical strain, and that a metal would corrode at a certain rate in its normal condition, and in other circumstances it would corrode more or less.

The PRESIDENT—That is when the plate begins to get weaker?

Mr. ANDREWS—It corrodes more rapidly. In the plate away from the buckling portion the corrosion was normal, but near the buckling the corrosion was increased by galvanic action set up by the part under the influence of strain and the part in normal condition; so they had not only the actual corrosion acting upon the plate, but they had also the corrosion increased by the galvanic action set up by the difference of strain. He had worked this out in connexion with a large number of metals, and hoped shortly to bring it before the Institution of Civil Engineers.

Mr. JEFFERSON said that in the boiler on the diagram (Fig. 1, Plate XIV.), the flue was provided with the Adamson ring or joint, which simply consisted in turning the flange at each end of each belt or length of the flue, and putting a ring between the two adjacent flanges. The reason for putting in the ring was that they could caulk on the ring better than on the flange. In flanging they diminished the thickness, and if the flanges were brought in direct contact they had no great thickness to caulk upon, but by putting the ring between they could make the joint much better. With regard to different strains in the boiler producing corrosion by galvanic action he was inclined to think that they could scarcely make a distinction between corrosion properly so-called and corrosion arising from galvanic or electric action. His own opinion was that the one did not take place without the other; that galvanic action was simply another form of the same action; that wherever they had chemical action—and corrosion was chemical action—they had galvanic action.

Mr. ANDREWS—Galvanic action increases chemical action.

Mr. JEFFERSON said, no doubt, if there were two actions one would increase the other, but he was inclined to consider them practically as parts of one action rather than as two separate ones. The grooving at the front end of the plates took place in a width of $\frac{1}{4}$ or $\frac{3}{8}$ inch at most, but they got another kind of grooving or channelling in the plates of boilers more particularly in the ends of plates close to the lap edge. Close to the lap joint on the fire side of the boiler they would often find the iron eaten away for a considerable distance. Wherever there was a lap joint, whether in a circular seam or in a longitudinal seam, the tendency was to bend the plate so as to put the latter in a direct line with the centre line of rivets. The line of resistance tended to lie in a straight line, and to upset the iron close to the edge of the lap on both sides. There were no doubt different strains in the iron caused thereby which might induce

galvanic action or corrosion, such as was frequently found to extend 3 or 4 inches from the lap. He was much obliged for the vote of thanks.

The PRESIDENT said the discussion would be resumed when the paper was published.

It was agreed that the discussion of all the papers on the agenda paper with the exception of that on "The Pumping Appliances used in the Sinking Operations at the Cadeby New Winning" be closed.

The PRESIDENT said he had received a communication from the Chesterfield Institute in reference to the joint meeting in April next, and it was agreed that the Secretary should write suggesting the second Saturday in April or the first Saturday in May as suitable days.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, JANUARY 14TH, 1893.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members, having been previously nominated:—

Mr. L. T. O'SHEA, Lecturer in Coal-mining and Chemistry, Firth College, Sheffield.

Mr. ROLAND ELSTONE, Mining Student, Summer Lane, Barnsley.

Mr. WALTER HARGREAVES read the following paper on "Some Systems of Underground Haulage at Messrs. Charlesworth's Collieries:"—

SOME SYSTEMS OF UNDERGROUND HAULAGE AT MESSRS. CHARLESWORTH'S COLLIERIES.

By WALTER HARGREAVES.

It has been suggested on several occasions that, in order to give continuity to the discussions on underground haulage, members should write papers, and come prepared with facts in connected form, pertaining to systems of haulage in operation at their own collieries.

In falling in with this arrangement, the writer simply records the various systems of haulage in operation at the collieries named, and whilst not claiming any novelty for these, puts them forward, with perhaps one exception, as examples of proper and economical systems chosen from the many, and best suited to the places in which they are working.

Of the 20 separate haulages in operation at these collieries, 18 are worked by engines fixed on the surface, and 2 are worked by engines underground, the steam being sent down the downcast shaft. Boilers in all cases have been eschewed. The 20 haulages may be classified as follows:—9 main-and-tail-rope; 6 main-rope; 5 endless-rope.

The total length of ropes running in these plants is about 40 miles. Compressed air and electricity have so far been avoided as motive powers, these not being yet thought within the range of practical economical systems; for whilst compressed air may be absolutely safe, and in many instances a most useful ally, yet from the point of view of economy the faint praise of gentlemen who have adopted it has practically sufficed to prevent its general adoption.

As to electricity, it may be perhaps premature to express such an opinion, but when the cost of electric traction as applied to the tramways of our large towns—where the conditions are certain to be much more in favour of the engineers' skill than in the narrow and often crooked passages, steep gradients, and ever varying circumstances of the mine—when the cost is said to be much greater than either horse traction or

steam traction; when we consider the experience of gentlemen who have tried electric haulage, and who only advise its adoption "when it is impossible to manage otherwise;"* the precise time at which this point may be reached is perhaps debatable, but cautious men may be excused if they hesitate before embarking in such a venture.

Opinions differ as to the merits and demerits of the various systems of haulage, and none as yet have proved equally adaptable to every condition of roadway in the mine, a fact which has been duly recognized in the erection of the works described.

Having regard to the many haulages of each kind at work, it is only necessary to describe a few. Commencing therefore with the most ancient system, the only one of its kind, and which has only a very short time to exist.

Rothwell Haigh Collieries.

No. 1 haulage is in operation at the Midland pit, Rothwell Haigh colliery. The engine is underground, geared 3 to 1, and steam taken to it from the surface. The engine-plane dips 1 in 17. The corves are mounted on rolleys, each rolley weighs 7 cwts. and takes 5 corves, and 10 rolleys compose a set. The empties gravitate in-bye, taking the rope with them. The corf-wheels are of the old type, the flange being on the plate while the rolleys run on edged-rails and have large wheels. The plane is 1,320 yards long and this system is fed by a tail-rope system.

It may be presumed that the object in using rolleys was to avoid the friction of the old corf-wheels: there only being 40 wheels running of an improved type, as against 200 of a very bad type; however, the writer does not offer any defence for the continuance of this arrangement, which will probably, as before mentioned, be of brief duration.

With regard to the cost of this scheme. The coal drawn along it is 2,200 tons per week, and the cost is as follows:—

	£	s.	d.
1 Engineman	1	13	6
1 Run-rider	1	19	0
1 Roadman	2	1	6
6 Loaders, 2s. 6d.	0	15	0
Rope costs £90 and lasts three years = per week	0	12	0
	£7	1	0

= ·76d. for 1,320 yards, or 1·01d. per ton per mile.

* *Trans. Fed. Inst.*, vol. iii., page 485.

Robin Hood Collieries (Figs. 1 and 2, Plate XV.).

No. 2 haulage is in operation at the Robin Hood colliery, and is on the main-and-tail-rope system. The gradient varies at this colliery from 1 in 12 to level. The engine is on the surface, and has a pair of horizontal 20 inches cylinders working 6 feet drums of wrought iron and geared $3\frac{1}{2}$ to 1. The main-rope is $\frac{5}{8}$ inch in diameter, tail-rope $\frac{1}{2}$ inch, and they are taken down the shaft in wooden pipes. The seam is only 2 feet 8 inches in thickness, and the corves carry 4 to 5 cwts. of coal; they are run in sets of 55 to 60 and travel at a speed of 12 miles per hour. There are six branches of roadways hauled, and the coal is trammed to the pass-byes of each branch by boys.

The points worthy of notice in this system are:—

a.—Simple method of getting round curves.

b.—Method of disconnecting all branches and working the one required alone.

c.—Method of moving haulage forward as the face advances.

Taking the points in the order named:—

a.—Ordinary 10 inches upright rollers running in frames are used, fixed on the inside of the curve to take the two ropes round, and as the inside rail is risen from 4 to 8 inches higher than the outside rail, this overcomes entirely the tendency to draw the tubs over to the inside; these curves are so perfectly safe that it is most unusual for the set to be thrown off the road while passing round, and the engineman cannot tell when he is rounding a curve. The curves vary in radius in this pit from 66 to 90 feet.

b.—Disconnection of branches. As shown in Fig. 1, there is one straight road from the shaft, with four branches, and one branch is divided into two more, making six in all. The usual thing in tail-rope haulage would be to make the straight-road rope always run, and stop the set at the branch road required to be taken, then couple the ropes, laying on the branch to the straight-road rope, and so proceed—thus the ropes of two branches are moved, but only one is passing coal.

This was done in the system under notice until about three years ago, when a pair of clippers, the invention of the enginewright, was introduced, which would act readily and would pass any sort of pulley, and also up the wooden conducting-pipes and on to the drum.

All the branches have idle ropes laid in and out, and when the set is at the pit bottom, the ropes of the straight-road are severed at any branch, and the rope between the shaft and the branch are joined by a pair of clippers, and so that branch works alone.

It was found three years ago that the engine-power was not sufficient to run the set at more than 5 miles per hour, on account of having so much dead rope to move. The clippers were then introduced, and an immense relief was experienced.

c.—The coal is worked longwall and the main haulage-gates are 8 chains apart. Owing to the thinness of the seam, slant cross-gates are put in every 2 chains right and left of the engine road, and as soon as the old cross-gate is finished, the return haulage-pulley is moved forward to the new cross-gate, and so the distance to tram the coal is never more than 150 yards, and averages about 70 yards. The faces move about 4 chains per year, so that the six haulage-pulleys are each moved twice a year or one per month. The cost of moving the pulley varies from £2 5s. to £3.

By this means horse-haulage has been entirely excluded, and for ten years there was only one pony in the pit, and this was used when night bye-workmen required timber, etc., to be moved. The amount of coal hauled is from 2,100 to 2,400 tons per week, and the cost is as follows:—

	£	s.	d.
1 Run-rider	1	16	0
2 Corporals...	2	16	0
1 Linker	0	12	0
1 Engineman	1	13	0
1 Roadman...	1	19	0
	£8	16	0

= ·94d. for 2,000 yards, or ·82d. per ton per mile.

The weekly cost of repairs to corves in this haulage is:—

	£	s.	d.
No. of corves, 550.			
Cost of material for repairs, including all small repairs and general rebuilding	1	11	0
Labour	0	15	0
	£2	6	0

The cost of labour alone is taken, as the cost of ropes cannot be easily got at. All the ropes used in this haulage have worked from eighteen months upward in the Silkstone seam of this colliery, the haulage of which is heavier than the one under notice.

An endless-rope haulage has recently been put down in the Beeston seam of the Robin Hood colliery by the writer, and is working fairly satisfactorily, but as the seam is a newly-opened one, and the endless-

haulage not called upon to do more than half the work it is capable of doing, comparison in the matter of cost cannot be made between this and the main-and-tail-rope.

The engine driving this haulage is at the upcast and 1 mile away from the downcast, it has an horizontal cylinder 18 inches in diameter, and 3 feet stroke, and is used for three purposes, viz.:—

1.—Hauling coal up incline on surface for fan boilers and its own, 1,320 yards.

2.—Pumping water for boilers from a well 200 yards away.

3.—Endless-rope haulage in mine, 3,600 yards.

As the latter alone concerns underground haulage we will name a few points:—The endless drum is 4 feet 6 inches in diameter; the rope, which is $\frac{5}{8}$ inch in diameter, passes $2\frac{1}{2}$ times round; the tension-pulley and screw are fixed on the surface, 60 yards from the engine-house at the empty-rope side: this has been found useful, as the haulage has been extended four times, and had the tension-gear been in the middle of the road at the terminus of the haulage, the road would have been to make much bigger each time. Such things are a consideration in thin seams; the arrangement is convenient also for the engineman who can see it constantly, and if anything is wrong remedy it, and also for splicing ropes, etc., as this may be done on the suface. The signals are all electric, and telephones are carried by the corporals, who communicate with the engineman when necessary, and this often occurs during the day.

The rope is taken down the upcast (no pipes), which is a fan pit, travels $2\frac{1}{2}$ miles per hour, and is divided by horizontal pulleys at the bottom. It runs on the top of the corves; the gradient varies from 1 in 8 to 1 in 50 and is for the greater part in favour of load; but for short distances, the inclination is 1 in 12 against the load. There are two curves, and these are fitted with unequal flanged pulleys hung in the roof. The corves are attached to the rope by lashing-chains of $\frac{1}{4}$ inch iron, about 12 feet long; the chain is taken three times round the rope and then laid in the hook; the number sent out on a chain varies from 3 to 15; the corves only carry 5 cwts.

At the curves, slides are placed to guide the corf and check-rails, so that if the corf does get off the road it is thrown on again. The approach to each curve is made to dip to the curve for either full or empty corves and to rise slightly away from the curve; by this means the lashing-chain, either back or front, is slack at the pulleys and passes easily, and in most cases the load passes round without assistance. The curves vary from 66 to 100 feet in radius. No attempt has been made to take out the cost of this endless-haulage for reasons before stated.

Thrybergh Hall Colliery (Figs. 3 and 4, Plate XV.).

At Thrybergh Hall colliery the whole of the machinery employed in hauling coal is fixed above-ground, and the ropes in all cases are taken down the pit in wooden pipes.

There are seven separate and distinct haulages in operation, and the particulars and work of each may be taken *seriatim*, and the drums called for convenience A, B, C, D, E, F, and G. The drums A, B, C, D, and G work the roads marked on Fig. 3 by the same letters; while drum F works the roads X, Y, and Z; and the drum E is not yet at work.

The seam worked is the Barnsley Bed averaging about 8 feet in thickness. The corves weigh 3¾ cwts. and hold 8 to 9 cwts. of coal; the wheels are steel and are 10 inches in diameter. The dip of the seam varies from 1 in 5 to 1 in 2·5, as shown in section (Fig. 4). The coal is delivered into the pit bottom by three roads, A and B on one road, C and G on another, and X Y Z on the third road. D delivers to the upcast pit bottom.

Taking the haulages in the order above stated:—A and B are two drums on one shaft driven by a pair of high-pressure engines, 26 inches cylinder, 5 feet stroke, direct-acting. The road marked A dips from 1 in 4 to 1 in 2·6; the empties therefore gravitate in-bye, taking the rope, which is 1⅛ inches in diameter, and 2,000 yards long, along with them. There are five stations in this plane and journeys are made to them in due order. Twenty-two corves compose a set and seventeen journeys constitute a day's work of eight hours. The speed run is about 8 miles per hour. The ropes last about fourteen months and work three shifts per day. The cost of hauling 150 tons per day of 8 hours on A is as follows:—

	£	s.	d.
5 Stations, 4 lads	0	8	0
1 Run-rider	0	5	2
1½ Roadmen	0	7	0
1½ Boys at bankhead ...	0	4	9
½ Engineman, brakesman, firer	0	4	8
	£1	9	7

= 2·36d. for 1,200 yards, or 3·46d. per ton per mile.

The B drum is 7 feet 6 inches in diameter with wrought-iron sides, and is working the road marked B on Fig. 3. The dip of this road is from 1 in 2·5 to 1 in 10, it runs parallel to A for 300 yards, and then turns off at an angle of 137°. As before said, A and B are on one shaft, and while A is being wound up, B is being braked down, and *vice versa*. The rope is 2,000 yards long, and 1⅛ inches in diameter; the load is twenty

tubs; speed, 8 miles an hour; life of rope, three shifts, fourteen months. The cost of hauling 125 tons per day, on B, is as follows:—

	£	s.	d.
4 Stations, 4 lads	0	8	0
Run-rider	0	5	6
Roadman	0	5	6
1½ Boys at bank-head ...	0	4	9
½ Engineman, firer, brakesman	0	4	8
	£1	8	5 = 2·72d. for 1,650 yards, or 2·96d. per ton per mile.

Steam is supplied by five 30 feet boilers of Cornish type, two of which have Fox patent tubes.

C, D, E, and F are each hauling separate districts, but are worked by an engine with a pair of high-pressure horizontal 24 inches cylinders. A and B, and C and D are main-rope systems; and E and F are two endless-rope systems, of which F alone is working.

Taking C first, it is geared 3 to 1; the drum is 7 feet 6 inches in diameter, with wrought-iron sides; rope, ¾ inch in diameter, 1,800 yards in length, and working the road marked C on Fig. 3, Plate XV., which dips 1 in 9, empties gravitate in-bye and take in the rope; the set is composed of 22 tubs, which are delivered on to the G endless-haulage at the junction shown. The speed run is about 8 miles per hour, and the present rope, which is the first put on, has been working twelve months.

The D drum is a *facsimile* of C, but the work is much more severe; the gradient is from 1 in 4 to 1 in 2·25; the rope is ⅞ inch in diameter, and 16 tubs make a set; there are four stations in this haulage, and the delivery is to the upcast pit bottom.

There are separate signals for each of the four haulages, named A, B, C, and D; separate sets of wires, No. 8. B.W.G., uninsulated, being taken down the shaft, and having separate bells in the engine-houses. Telephones are used, so that communication can be held between the engineman and those in the pit; this is of great importance in mines of such formidable dips as that noticed.

The F haulage, as before stated, is an endless-rope scheme worked from the same engine as C and D. The F drum is geared 10 to 1; a clutch being used for throwing the drum in or out of gear. The rope, which is 4,700 yards long and ⅞ inch in diameter, passes 4½ times round the drum and travels from the pit bottom to the point marked X on Fig. 3, Plate XV., before commencing work. It then passes on to the point marked W, where a set of three wheels are fixed on a 6 inches upright shaft, the rope is taken round the middle wheel 3½ times,

and this friction is used for driving the other two wheels. These two wheels, which may be called Y and Z, are provided with clutches to throw in and out of gear at will. Taking Z for the top wheel, the rope, which is $\frac{3}{4}$ inch in diameter, is taken round Z $3\frac{1}{2}$ times, and then passes on the level for 100 yards, and then up an ending for 400 yards, which is slightly in favour of load, to the point Z^1, where a throw-down fault of 19 yards has been tunnelled at a gradient of 1 in 2·25. The wheel Y is working on the level in the opposite direction, and to the north of W; the rope is $\frac{3}{4}$ inch in diameter and passes round the wheel $3\frac{1}{2}$ times, it then works the level for 800 yards and 500 yards of ending to Y^1; the whole of this is in favour of load; the throw is being tunnelled out at Y^1 in the same manner as at Z^1, and the ropes will then be taken forward.

The tension-pulley in both Y and Z is fixed at the end of the ropes; it stands on a rolley, and is tightened by a screw. The tension-pulley for the driving-rope in this scheme is fixed about 300 yards in-bye from pit bottom on the empty-rope side. The corves, in sets of 3 to 20, are attached to the ropes by lashing-chains, made from $\frac{1}{4}$ inch iron, 14 feet long; speed travelled, 2 miles per hour; all ropes travel on the top of the corves. At W, a person is in charge of the clutches, and the branches Y and Z signal to him when they want stopping; the signals are electric, and the main driving-rope signals to the engineman at the surface.

The F Y Z haulage has only been in operation about twelve months, but is doing admirable work, and the advantage derived from the gradient in favour of load renders the steam-power required practically *nil*.

The G haulage is an endless-rope driven by a pair of horizontal engines, 12 inches cylinders, geared $4\frac{1}{2}$ to 1. The rope is 4,600 yards long, $\frac{3}{4}$ inch in diameter, is taken $4\frac{1}{2}$ times round the endless wheel and passes down the upcast shaft; it is brought into the road G, near the pit bottom. The work of this rope is favourable, the gradient being slightly in favour of load; the tubs are lashed by chains back and front on to the ropes, and the rope travels on the top of the corves; the speed is 2 miles per hour. This haulage is fed by self-acting inclines on the top side, and by the C main-rope haulage on the low side. The life of ropes on this system is about two-and-a-half years. The cost of hauling 300 tons per day, on G, is as follows:—

	£	s.	d.
Engineman ...	0	2	0
6 Lads	0	12	0
2 Roadmen... ...	0	11	0
Firer	0	4	0
	£1	9	0

= 1·16d. per ton for 2,000 yards, or 1·02d. per ton per mile.

The weekly cost of repairs to the 1,600 corves in use is as follows:—

	£	s.	d.
Cost of material for repairs, including all small repairs and general rebuilding ...	5	7	0
Labour...	3	3	3
	£8	10	3

It is estimated that 85 per cent. of the breakages occur on the main-rope inclines.

In conclusion, though the description of the haulages in operation may not be as complete as desirable, it is hoped that the items of interest which individual members may have looked for and not found may be brought out by discussion, and any additional particulars will be willingly given by the writer.

The PRESIDENT said that before the discussion took place he wished to propose a vote of thanks to Mr. Walter Hargreaves for his paper.

Mr. W. HOOLE CHAMBERS said he had great pleasure in seconding the resolution. Rope-haulage was a subject of very great importance to mining engineers, and the most economical way of applying it to the varying circumstances of the mine was one of the most important things to which a colliery engineer could devote his attention. He agreed with the author of the paper when he said they could not lay down any system of rope-haulage which would be suitable for every condition and all the difficulties they had to contend with in colliery working. He had given his reasons in his paper* recently read before the Midland Institute for generally preferring the endless-rope system, but it was patent to mining engineers that there were circumstances in which that might not be the best system to adopt. The Institute would accord to Mr. Hargreaves a very hearty vote of thanks.

The resolution was unanimously agreed to.

Mr. R. WORDSWORTH said that the question of repairs ought to be taken into consideration seeing that with the endless-rope they seldom got serious damage done, whilst with the tail-rope system they often had accidents costing upwards of £50. If this item was included in the costs, he thought the figures would favour the endless-rope system.

Mr. BENNETT asked what particular one of the three or four widely varying systems of electric haulage was referred to?

Mr. WARD said there was no haulage by electricity or steam-power when he was a boy. The haulage when he first went down a pit, sixty years

* *Trans. Fed. Inst.*, vol. iii., page 970.

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To illustrate Mr. Walter Hargreaves' Paper on "Some Systems of Underground Haulage &c."

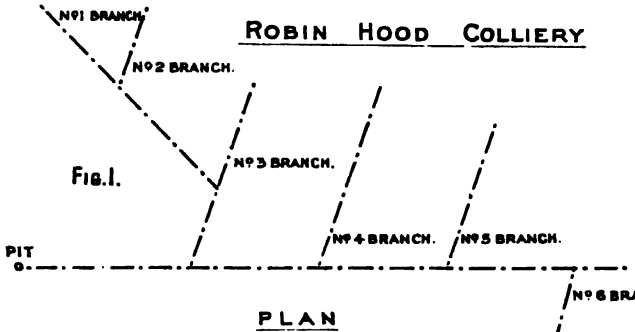

FIG. 1.

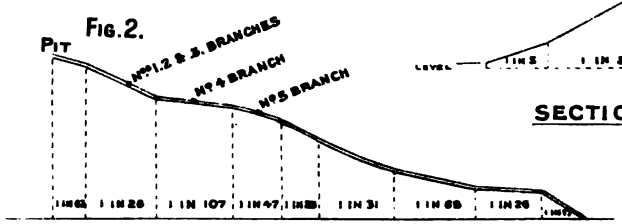

FIG. 2.

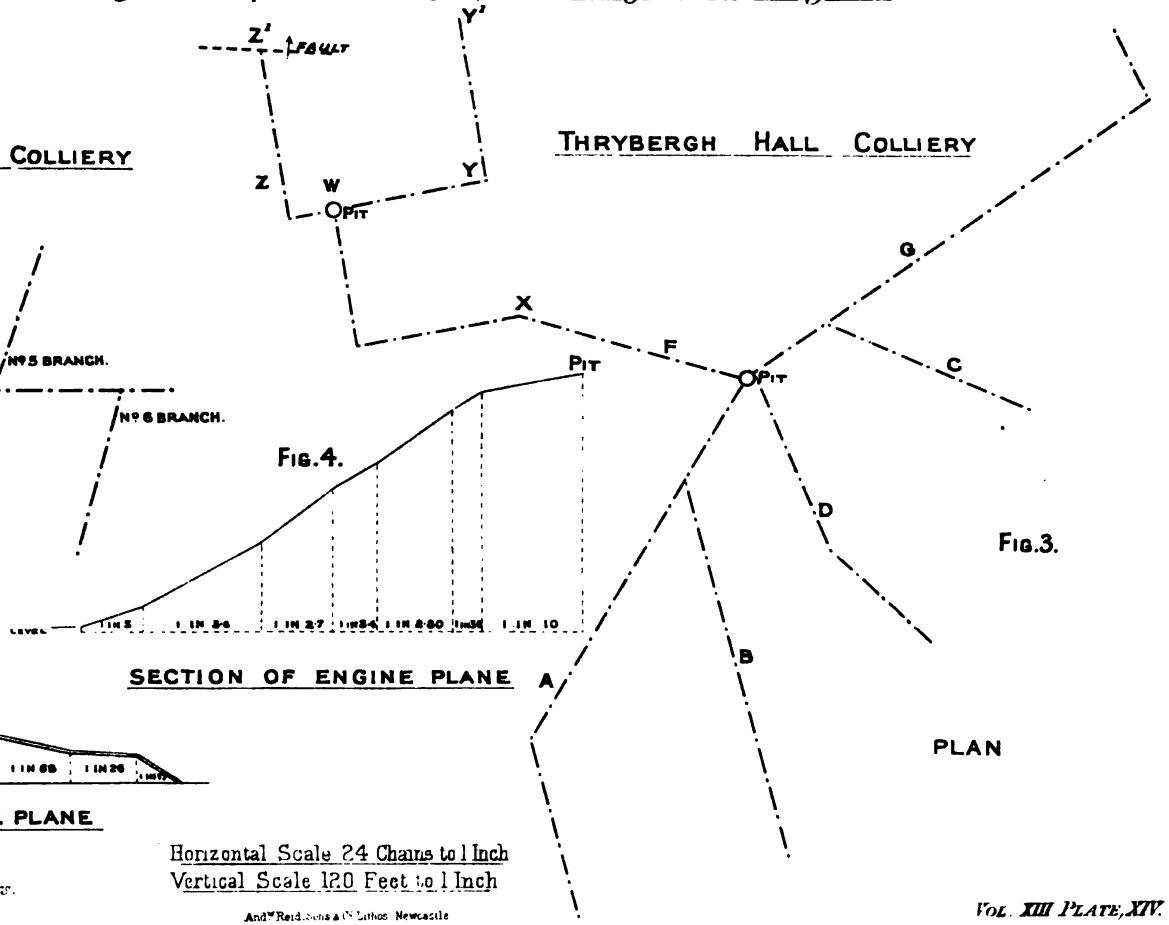

FIG. 3.

FIG. 4.

Horizontal Scale 24 Chains to 1 Inch
Vertical Scale 120 Feet to 1 Inch

And^w Reid, Sons & Co. Lithos Newcastle

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ago, was by means of a belt round the loins and a chain between the legs of the person hauling, who went on all fours like a dog. The first improvement was effected at the Kexbro' Field collieries belonging to the Messrs. Wilson, who used metal "tram-plates."

The PRESIDENT—That is the flanged rail?

Mr. WARD—This introduction of the tram plate or L-iron took place fifty-nine years ago, in 1833. The Messrs. Wilson went from Silkstone and sunk a pit in the Kexbro' Field. There was a large fault, and they found the Kent Main instead of the Silkstone coal.

The PRESIDENT—Then the first haulage on wheels took place in this district in 1833.

Mr. FITTON said that in some cases the inclination was in favour of the load. Were the tubs or train attached at both ends or only by one lashing-chain?

Mr. WALTER HARGREAVES replied that the tub was attached at both ends.

Mr. FITTON said that where the road was in favour of the load, if the corves were not attached at both ends, the chains would slacken by the twisting of the rope, and would consequently become unhooked.

The PRESIDENT asked what was the radius of the curve? and further said that the cost of repairs formed a serious item in the rope system of haulage.

Mr. WALTER HARGREAVES did not agree as to the costs of repairs, as the repairs with some of the endless-rope systems he had described were greater than with the tail-rope systems. The trains ran at a fairly high speed, but the number of breakages was very small. In a pit with 600 tubs running, one old man kept them all in repair, changed the broken wheels, etc., whilst with the endless-haulage at Thrybergh, he believed that there was a considerable number of tubs broken every week. Mr. Wordsworth assumed that the breakages were greater with the tail-rope than with the endless-rope system. His information respecting electric haulage was obtained from papers read by others; he had no particular system in view. In endless-rope haulage a great deal depended upon the straightness of the roads. If the roads were crooked, every expense was greatly enhanced. The straighter the roads, the easier the work and the less the expense.

The PRESIDENT said these remarks applied equally to every form of haulage.

Mr. HARGREAVES—But more especially to the endless-rope system.

DISCUSSION ON MR. WM. HENRY CHAMBERS' PAPER ON "THE PUMPING APPLIANCES USED IN THE SINKING OPERATIONS AT THE CADEBY NEW WINNING."*

Mr. W. HENRY CHAMBERS said he had tried to explain as concisely as possible the methods that they adopted for dealing with the water. The pumping was completed and the pumps dispensed with when the paper was written.

The PRESIDENT asked if they had been able to use any of the pumps and material after they had finished pumping ?

Mr. W. HENRY CHAMBERS replied that all the plant had been sold except one pump, which had been lent.

The PRESIDENT said that a ready sale was one of the advantages of using smaller pumps. If they had used a large pump with a 24 inches barrel, a considerable quantity of appliances would have been left on their hands for several years.

Mr. W. HENRY CHAMBERS said they had been able to dispose of the whole of the material after they had done pumping, at slight reductions on cost prices. Many of the pipes had been sold at cost price, and they could have sold the remainder, but were keeping them for their own use.

The PRESIDENT asked if any member could say what chance there would be of disposing of a pumping-plant with a 24 inches working barrel ?

Mr. W. HENRY CHAMBERS said he was erecting a bridge, and had bought a lot of pump-trees at the price of old iron, to be used as columns for the bridge.

Mr. J. E. CHAMBERS asked what was the advantage of having pumps of unequal area over those of equal area?

The PRESIDENT said this was a question of pumping with the pumps suspended in the shaft, instead of having large machinery on the surface and the working-barrels in the shaft. Mr. Chambers had found great advantage from the suspended pumps.

Mr. W. HENRY CHAMBERS said the little rams were half the area of the bottom of the plunger. If they had the full area of the bottom of the plunger to force up the pipes at each stroke they would have required a much larger cylinder, and there would have been a great waste of steam in filling the cylinder at every lift.

Mr. J. E. CHAMBERS said what he meant was, why not have the bottom of the plunger of equal area with the top one, instead of having two of equal size ?

* *Trans. Fed. Inst.*, vol. iii., page 513.

Mr. W. HENRY CHAMBERS said that both at the up and at the down stroke they forced the same quantity up the tube, and so got a continuous flow.

Mr. J. E. CHAMBERS rejoined that was what he meant—having pumps of unequal areas they got an equal flow.

The PRESIDENT said Sir William Armstrong first introduced that motion for the purpose mentioned.

Mr. HARGREAVES said there was much less weight, compared with the old system of pumping with quadrants and pumps 24 or 25 inches in diameter.

The PRESIDENT asked what was the largest quantity of water pumped ?

Mr. W. HENRY CHAMBERS said that he put it less in the paper than it really was, because there might have been a doubt raised as to the quantity of water they could pump. He tested the pumps, one after another. There were three pumps working in the shaft, and he found they were pumping in excess of the calculated quantity, that was, up to 80,000 gallons an hour each. Some of the pumps were running 45 strokes a minute for weeks together.

The PRESIDENT—Do you wish us to understand that the total quantity within the pit produced by the strata was 240,000 gallons per hour ?

Mr. W. HENRY CHAMBERS—No ; there were six pumps, and they averaged 70,000 gallons per hour each.

The PRESIDENT—At one particular time ?

Mr. W. HENRY CHAMBERS—Yes ; and that volume of water was pumped for three months.

The PRESIDENT—So that you had 420,000 gallons per hour ?

Mr. WARD said he had been much pleased with the Bailey pump. He had one weighing (with pipes and water, 70 yards up to the top of pit) 12½ tons suspended on a galvanized steel rope in a pit, which was flooded, and pumping 17,000 gallons per hour at 42 lbs. steam pressure.

The PRESIDENT said he had never known a sinking in Yorkshire that had to deal with 420,000 gallons per hour.

Mr. W. HENRY CHAMBERS said they tubbed it off in very short lengths, but it soon overtook them again. The full quantity followed them down for 110 yards. Until they got 80 yards down, they were not able to fix a crib, and that was the reason why they adopted this system of pumping. It was out of the question putting down heavy quadrants—heavy cast-iron pump-trees because the ground was not strong enough

to carry the weight. The pit was standing on timber, and the water coming into the pit through the layers of fissured sandstone with the boulder clay between, washed it in like mud; and it was actually mud.

Mr. HARGREAVES said they could not have applied the old pumps, but the new system being lighter they were able to deal with that large volume of water.

Mr. WARD said another advantage of this pump was that they could lower it down as the water receded, adding other pipes at the top, and by that means effecting a great saving.

Mr. J. E. CHAMBERS said what he wanted to arrive at was the advantage of the two rams. Was the advantage in the pumps or in the power required in raising the water?

Mr. W. HENRY CHAMBERS said it was owing to both of these advantages. If they had the plunger forcing direct to the top they would require a steam cylinder of sufficient area to overcome the pressure of the water against it. Then, when it reversed and was taking the other stroke the cylinder, full of steam, was doing nothing.

Mr. J. E. CHAMBERS said at each stroke of the engine it was taking half the water from the bottom plunger. If they had it the same size as the bottom one, it would deliver an equal quantity of water.

The PRESIDENT said the question was well answered in Sir William Armstrong's paper wherein he dealt with heavy pressures of 700 lbs. per square inch, where they could see the difference in the two raises more than they could in the case of 50 or 100 lbs. to the inch.

Mr. W. HENRY CHAMBERS said they had a 22 inches cylinder having an 18 inches ram, lifting 100 yards with 80 lbs. of steam. If they had not had the top rams they would have required double the size of steam cylinder to force it up.

Mr. J. E. CHAMBERS said they could have had the cylinder the full size of the top rams.

Mr. W. HENRY CHAMBERS said in that case they would have had one stroke doing nothing.

The PRESIDENT said he knew the advantage when they had a wet subsoil. In North Wales, at the West Mostyn sinking, on the banks of the River Dee, they could not have done anything except by suspending pumps in the shaft.

Mr. W. HOOLE CHAMBERS moved, and Mr. H. B. NASH seconded, a vote of thanks to the President for his conduct in the chair, which was carried, and the meeting ended.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, NOVEMBER 14TH, 1892.

MR. WILLIAM HEATH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

ORDINARY MEMBERS—

Mr. WATSON FOGGO, Mechanical Engineer, Brereton Engineering Works, near Rugeley.

Mr. ALFRED JACKSON, Mechanical Engineer, Park Hall Collieries, Weston Coyney, near Longton.

Mr. JAMES MUIRHEAD, Mechanical Engineer, Grove Road, Fenton.

DISCUSSION ON MR. R. H. WYNNE'S PAPER ON "COAL: ITS VARIETIES AND APPLICATION TO MANUFACTURES AND THE ARTS."*

Mr. R. H. WYNNE said he was prompted to write the paper by one which had previously been contributed by Mr. Taylor on "The Common Definitions of Coal."† He spoke of the varieties of coal, a point which Mr. Taylor had not touched upon ; and no doubt the numerous varieties were in some measure the cause of confusion in the definition of coal. He (Mr. Wynne) had called the attention of the members to what had been said on the subject by the late Sir Warington Smythe, Dr. Percy, and others. There was another point which might perhaps create a little interest. It was referred to in geological text-books on the Pennsylvanian

* *Trans. Fed. Inst.*, vol. iii., page 234. † *Ibid.*, vol. iii., page 232.

coal-field—the change in the character of the coal from bituminous to anthracitic in passing from one stage of the coal-field to the other; and comparing it with the North Staffordshire coal-field, where the coal on the eastern side of the field and of the synclinal and anticlinal axes was non-bituminous, or only slightly bituminous, it became on the western side, which was more faulted, bituminous. He thought this might become of some interest in endeavouring to solve the reason why the mines in Pennsylvania were most faulted where the coal was perfectly anthracitic. The reason given was that the solidification and disturbances had let out the volatile matter, and caused the coal to become anthracitic.

Mr. W. N. Atkinson said that he was not quite clear whether Mr. Wynne meant that the Pennsylvanian coal-field was faulted in the anthracite region, while in North Staffordshire in the faulted part the coal was bituminous.

Mr. Wynne said he did.

Mr. Atkinson said that the explanation seemed contradictory.

Mr. Wynne observed that that was the point to which he wished to call attention.

Mr. Blaikie said that Prof. Williamson in a recent lecture referred to this point, and illustrated his remarks by saying that if the cork were left out of a bottle of Glenlivet the spirit would evaporate. He seemed to think there had been a sudden closing up of the measures in the formation of coal and there was no time for the gases to escape. Prof. Williamson gave an analysis of cannel. He (Mr. Blaikie) found it to be distinctly of vegetable origin.

Mr. Thomas Ashworth said he had known a case where the more faulty and friable the coal, the better it was for gas-making. The friable coal would produce more gas than the coal taken from where it was more solid.

Mr. E. B. Wain asked if chemical analysis showed the difference between coking and non-coking coal? Chemists were not always quite accurate in their analyses. He remembered a short time ago sending a sample of black carbonaceous shale locally known as "hustle" for analysis, and the chemist said he had applied all the known tests for fuel to it, and he had come to the conclusion that it was coal. There did not seem to be any record of any difference in the component parts of coking and non-coking coal.

Mr. Rigby said that at the Audley colliery, where they got what was essentially a gas-making coal, the seam was especially cut up with faults—a plan of the workings was more like a spider's web than anything else.

The coal was sold for gas-making. One remark of Mr. Wynne's might require a little modification. The coals in North Staffordshire were described as bituminous. Some were more so than others. The upper series of the North Staffordshire coal-field were open burning and less bituminous than the lower series, so that the remark did not apply to the whole of the coal-field.

Mr. JOEL SETTLE confirmed what Mr. Rigby had stated as to the lower series being bituminous. The Rough Seven-feet coal was not bituminous, and it was very dirty. The Moss coal was open-burning, and friable; it was strange that the slack was bituminous, but the coke would not stand a big blast upon it, and was inferior to that of the lower seams.

Mr. WAIN asked what was the element in a coking coal that was wanting in a non-bituminous coal?

Mr. RIGBY said that seemed to lead to the question, what action took place in making coke? There was a certain amount of carbon in all coal, but it was the presence of a larger proportion of bitumen in certain coals that enabled them to be coked.

Mr. WAIN said there was the same amount of fixed carbon in the coals on each side of the district, and it seemed almost a mechanical difference that on one side it had not the power of cohesion. There had been some experiments with bituminous matter, mixed with free burning coal, but he thought they had not been successful in making coke from the mixture.

Mr. SETTLE said he made a test with some slack from the Cockshead seam; it burnt away freely, but it would not coke. With regard to cannel, he thought it was a new theory that it was not vegetable matter. The cannel was as a rule good for gas-making and its products. One Lancashire cannel sold for 45s. a ton. Though having other good qualities it would not coke. It showed that they could get coal to produce gas and not coke. He did not suppose that the faults affected the quality. In other districts they got a lot of inferior coal just before and just after a fault; but in North Staffordshire it was very good immediately on approaching a fault and after. That would account for what Mr. Ashworth said as to its being of good quality when near a fault.

Mr. WYNNE observed that Mr. Settle had referred to the Cockshead coal. He believed the Eight-feet Banbury on the western side of the district was the equivalent of the Cockshead on the other side of the field. The latter was remarkably free from faults and was scarcely bituminous, whereas on the western side, as he said before, it became highly bituminous. The difference between bituminous and free-burning and steam coal

he took to be that one had more volatile matter than the other. Mr. Wynne produced a plan of the district made forty years ago, and said he would endeavour in the course of a few weeks to prepare a supplementary paper and collect a few facts and analyses that he had met with since writing the paper now under discussion. It was a remarkable thing that, in speaking of cannel, though it was the best gas-producing coal it made no coke, or scarcely any. He gave a section in his paper, supplied to him by Mr. Bridgett, relating to cannel in the colliery he was connected with. There were 2 feet 10 inches of coal; then 7 inches of cannel, and 1 foot 5 inches of coal. There was free-burning coal above and below, and cannel in the middle.

The PRESIDENT thought that very great credit was due to Mr Wynne for the way in which he had brought the subject forward, and on his (the President's) suggestion,

The further discussion of the subject was then adjourned.

DISCUSSION ON MR. W. N. ATKINSON'S PAPER ON "THE REPORT OF THE AUSTRIAN FIRE-DAMP COMMISSION."*

Mr. W. N. ATKINSON remarked that there were one or two points in the paper to which he wished to direct attention with a view of eliciting the opinion of members thereon, viz., "The composition of gas liberated by coal heated in water at 212 degs. Fahr. was studied, chiefly with a view to determine the danger of the dust from each kind of coal. The analyses showed that in the gas enclosed in lignite, carbonic acid gas was generally the chief constituent (36·78 to 89·65 per cent.), whilst in coals it was methane with carbonic acid gas varying from 1 to 56 per cent. As to the amount of gas, 1,543 grains (100 grammes) of lignite always gave less than ·061 cubic inch (1 cubic centimetre) of gas, coal liberated up to 30·5 cubic inches (500 cubic centimetres), often containing a certain quantity of ethane (0·90 to 2·45 per cent.) in the Ostrau coals, and up to 19 per cent. in the Rossitz coals." Then with regard to lignite. One of the arguments which had been used in France to show that coal-dust alone could not cause an explosion, was that there had been no explosion in lignite-mines which were very dusty. It was possible that the explanation of that might be found in the fact that lignite contained such a large proportion of carbonic acid gas. Then, with regard to the

* *Trans. Fed. Inst.*, vol. iii., page 531.

indications of fire-damp given by different lamps, the length of the caps given with the Mueseler lamp appeared to be very much greater than any he had heard of before with a given quantity of fire-damp. What the explanation of that might be he could not say. With respect to the quantities of air considered necessary for the proper ventilation of different collieries, the quanties of air mentioned in the Austrian report appeared to be very small compared with the quantities deemed necessary in English collieries; but there might be a reason for that which did not appear on the surface. The quantity of air circulated in English collieries and its distribution had been somewhat severely criticized by two French engineers—Messrs. Pernolet and Aguillon—who said:—"Finally, all the details we have described and all the observations we have made on the spot conduct us to the general conclusion that, if at the bottom of the English shafts there are enormous volumes of air, the quantities really and usefully available in the working-districts are, all things considered, rather inferior than superior to those admitted in Belgium and France, and the circulation of the air in the working-places is not so well disposed for the removal of fire-damp." He (Mr. Atkinson) did not agree with the criticism altogether, because he had had no experience of the French and Belgian collieries, and he thought a mere statement of the amount of air per man, or per ton of coal got, was not necessarily any guide as to whether the mine was well ventilated or otherwise. There was one other point mentioned which struck him as being contrary to his own experience: that was the statement that "barometrical pressure did not affect the liberation of carbonic acid gas." As far as his experience went, it did affect it: it was given off to a greater or less extent with a high or low barometer.

Mr. Bridgeit said he did not think the fact that no explosion had occurred in a lignite mine was any argument against dust being explosive in other mines.

Mr. H. R. Makepeace said there seemed to be a very great difference between the results obtained by the Austrian Fire-damp Commission when using the Mueseler lamp as a fire-damp indicator and those given by Mr. Sawyer in a paper read before this Institute some time ago.* The Austrian Commission appeared to have got unusually large caps with different percentages of gas—almost double the lengths obtained by Mr. Sawyer with the same percentages. With 2 per cent. of gas Mr. Sawyer gave the height of cap above the wick-tube as ·25 inch. Whereas the Austrian

* *Trans. North Stafford. Inst.*, vol. vii., page 160.

Commission gave ·45 inch. With 3 per cent., Mr. Sawyer gave ·37 inch, and the Austrian Commission ·75 inch; with 3½ per cent., Mr. Sawyer gave ·67 inch, and the Austrian Commission ·98 inch; with 4 per cent., Mr. Sawyer gave ·985 inch (the pointed cone of the cap just reaching to the bottom of the chimney), with the same percentage the Austrian Commission stated that "the point of the cap disappeared in the chimney," which would give a cap at least ½ inch longer than Mr. Sawyer's, as in the lamp used by Mr. Sawyer—a typical Belgian lamp—the length of the chimney below the diaphragm was 1·063 inches, and that used by the Austrian Commission was given as being only ·59 inch below the diaphragm, a difference of ·473 inch in length. The lamp used by the Austrian Commission appeared in this respect to be very different from the Belgian type, in which, according to Mr. Sawyer, the practical limit allowed for length of chimney below diaphragm was from ·985 to 1·142 inches. In addition, the Austrian Commission's Mueseler lamp had a glass over ¼ inch higher than Mr. Sawyer's, which would bring the bottom of a chimney still farther above the wick-tube. He (Mr. Makepeace) did not know how Mr. Sawyer obtained his figures, whether by actual experiments made in this district or from experiments by others, but probably some member of this Institute would know how the results were obtained; but, however they may have been obtained, we have in these two papers two scales showing the lengths of cap on the flame of a Mueseler lamp as indicating certain percentages of gas, one giving nearly double the lengths given by the other. In the experiments with explosives, the report did not appear to say how the dust was introduced and the state of the dust, whether lying on the floor or floating in the gas and air mixture at the moment that the shots were fired. Had the soda-wetter dynamite, which was so favourably reported on by this Commission (but as Mr. Atkinson had pointed out was not approved of by the French Commission) ever been used in this country or anywhere, except experimentally? He was glad to see that the Commission condemned the Bickford shot-lighter on account of the sparks it might emit. About two years ago a man was very seriously burned in this district from the ignition of fire-damp by a Bickford shot-lighter.

Mr. J. R. Haines said he had had the pleasure of being present on several occasions when Mr. Sawyer made his experiments, and his percentages were produced as nearly possible by using known quantities of coal-gas in the testing-boxes. His table was brought out afterwards from those tests. He understood that the Austrian Fire-damp Commission used benzine, which was more sensitive than seed oils. The tube of the lamp was shorter, and would cause a greater elongation of the flame.

Mr. E. B. WAIN quoted the remarks of Mr. Atkinson on page 539* respecting fire-damp indicators, and said probably the gas used was more sensitive than the Longton Corporation gas that Mr. Sawyer used.

Mr. W. BRIDGETT said it distinctly stated that 2 per cent. created a pointed cone. In Mr. Sawyer's it did not, there was no pointed cone.

Mr. W. N. ATKINSON said with regard to the cap-lengths of the Mueseler lamp they were higher than he had read of before. He always understood that 2 per cent. was practically the first indication that could be perceived, whereas they give 2 per cent. and ·45 inch. When they went on such fine points and small percentage it was not fair to make a comparison between lighting gas and fire-damp at all.

Mr. WAIN asked if there was anything in the original report as to the quantity of coal-dust used in mixtures—the proportions of coal-dust and gas used ?

Mr. ATKINSON replied that he could not answer that question, because the paper was an abstract of a French translation of the report, which was very bulky. He should like to hear whether any member had noticed how carbonic acid gas behaved with regard to change of pressure.

Mr. BRIDGETT said he had known instances where, if there was a fall of barometer, they could scarcely get into the mine at all. His experience was that, where there was much carbonic acid gas to be dealt with, in change of weather it showed itself plainly.

Mr. ATKINSON intimated that that was his experience, and he was surprised to find it stated in the report that the barometer appeared to have no effect upon the issue of carbonic acid gas.

Mr. STATHAM testified to the correctness of the statement made by Mr. Bridgett. He had known men stay at home when the wind was westerly and there was a fall of the barometer. He had known several cases where it was impossible to work when there was a falling barometer. In a great many cases there had been evidence that, though carbonic acid gas might not appear quite so sensitive as fire-damp, it did come out of the gob on the fall of the barometer.

Mr. JOEL SETTLE thought it would not be right if they did not admit that carbonic acid gas would make itself plainly shown during a fall of the barometer. In a small mine which they were opening out in the Moss coal, they never expected to find gas, but they were opening out old workings, and whenever there was a fall of the barometer the men could not get into their working-places.

The PRESIDENT thought they need not hesitate to assure Mr. Atkinson

* *Trans. Fed. Inst.*, vol. iii.

that the report of the Austrian Commission was inconsistent with facts respecting the issue of carbonic acid gas. He remembered the time when that gas laid one-half of the workings idle if the wind was from the west or south-west, and it was a common phrase at Burslem to say they could never get into the workings with it. He was speaking of the Peacock and Spendcroft seams. People engaged in those seams played day after day when the wind was from the south or south-west; sometimes for weeks together they could not get to work. Some seams with equal ventilation gave off more carbonic acid gas than others. The Burntwood seam gave off a large amount. The same remark applied to the Cannel-row, which was an open and porous seam, though there was strong ventilation in it when the wind was from the north or north-east, but when the wind was from the south the ventilation was overpowered and the mine stopped. The men worked with candles, and he remembered the time when scarcely a safety-lamp was to be seen, but during bad weather one-half of the district might be lying idle from the cause he had named. There was another point Mr. Atkinson mentioned which might be noticed, if the report of the French engineers was correct, that although in the English mines there was a larger amount of ventilation at the pit bottoms, it was not passed round where it could be of most service. This did not redound much to the credit of English mining engineers, as a mine was not well ventilated if the air was not carried to the working-faces.

Mr. WILSON, referring to the remarks of Mr. Atkinson on the report of the French engineers on ventilation, said he had the pleasure of giving them some information with respect to ventilation of one of his collieries, and he did not think there would be above 10,000 cubic feet loss out of the 140,000 cubic feet circulating through that mine. Adding the splits up together it nearly corresponded with the total amount in the main return.

The PRESIDENT said that statement thoroughly refuted the statement of the French engineers.

Mr. ATKINSON observed that the French engineers based their calculations on an average of 18 or 20 collieries. In some instances they spoke of a loss of 50 per cent. in reaching the working-places; in others they said it was 30 per cent. But, taking the average of the whole, their conclusion was that a large proportion of the air was lost by leakage or used for ventilating stables, feeding boiler-fires, or other purposes, without reaching the working-places at all. He (Mr. Atkinson) knew himself that there was no doubt a very considerable leakage, which in some cases might be prevented. The case mentioned by Mr. Wilson might be a

case where the loss was small; but he (Mr. Atkinson) should think there were few collieries where, out of 100,000 cubic feet of air, 90 per cent. actually reached the workings. That might have been a longwall pit, where the air went straight to the face, but in some pits there were many doors and stoppings not so tight. As a general rule there was a considerable quantity of air either used or wasted before it actually reached the working-places. It did not follow that the French and Belgian mines were any better ventilated than our own, because the volumes used were smaller.

Mr. WILSON said the pit to which he had referred was a bord-and-pillar pit.

Mr. WAIN enquired what parts of the country the French engineers visited?

Mr. ATKINSON replied the North of England, Scotland, and South Wales, and one or two other districts, but not North Staffordshire.

Mr. WAIN thought most of them would be bord-and-pillar workings.

Mr. ATKINSON believed that was very probable.

Mr. R. H. WYNNE observed that a good deal was said in the report as to the Pieler lamp. It was quite as much condemned there as by Mr. Atkinson. He (Mr. Wynne) considered it to be almost useless as a fire-damp indicator. As to the carbonic acid gas given off on the lowering of the barometer, there could be no doubt of that. The barometric pressure applied to all gases, the increase or decrease in the volume being inversely as the pressure, not only in carburetted hydrogen, but in atmospheric air and other gases. Therefore he should say that it was a blunder for the Austrian Commission to make such a statement.

Mr. ATKINSON remarked that, with respect to carbonic acid gas the possible explanation of the statement made by the Commission was that their mines did not produce carbonic acid gas, and that it might be only that produced by the breath of the men and horses, etc., and in that case the fall of the barometer would have no effect.

Mr. WAIN said the Austrian Commission in one place stated: "The volumes collected during equal spaces of time never varied with the barometrical pressure," and in another place they said "Neither the velocity of the wind on the surface nor storms had any effect on the liberation of fire-damp in artificially ventilated mines." He knew there were in this country collieries where, when the barometer was low or a heavy storm was raging, men were not allowed to work. It seemed an extreme statement on the part of the Commissioners that such atmospheric changes had no effect on the liberation of fire-damp.

Mr. ATKINSON said his experience was that storms and sudden changes had an effect upon all mines.

Mr. RIGBY said in the rearer workings he had known similar effects produced to those to which the President had called attention.

At the suggestion of the President the further discussion of the paper was adjourned.

The meeting then closed.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, OCTOBER 6TH, 1892.

MR. W. F. CLARK, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

TECHNICAL EDUCATION COMMITTEE.

The Technical Education Committee reported that the scheme of mining lectures and instruction which they had recommended to the Staffordshire County Council had been approved and adopted. There would be eight centres at which lectures would be given; at six of these centres there would be fortnightly lectures, and at the others, two lectures or advanced classes would be held. A grant of £2 was to be made to each of the students showing themselves qualified after examination, to enable them to attend the advanced classes to be held at Hednesford and Old Hill. The President of the Institute was appointed the examiner, and Mr. W. Charlton the lecturer.

Messrs. Henry Dyke, Dennis, and William Charlton were elected Members of the Institute.

THE LONDON CHAMBER OF COMMERCE.

The SECRETARY again brought forward the letter from the London Chamber of Commerce as to the question of appointing a Minister of Mines, and after a discussion it was decided the members could not express an opinion with the scanty information before them.

COAL-DUST AND EXPLOSIONS.

The SECRETARY read a cutting from a newspaper on "Coal-dust in Explosions," which was the result of an interview with a Cambridge professor, who rather reflected upon mining engineers.

The PRESIDENT said the cutting was from the *Daily Chronicle* of a recent date, and he should like to hear what the members thought of it.

Several members expressed the opinion that men who had simply spent their time in gaining a theoretical knowledge sought this evil system of interviewing in order to put forth their views instead of writing a paper or expressing their ideas in a more tangible form for discussion by mining engineers. As a matter of fact, no one had taken more pains to investigate the question and put it in a practical fashion than mining engineers themselves. They had been for years, and were at the present time, experimenting in order to arrive at a solution of the matter, and there was a Commission sitting on that subject at the present moment.

Mr. W. J. HAYWARD thought the provisions of the Mines Regulation Act provided generally for the suggestions contained in the extract. With regard to watering, practical men were already quite aware of the circumstances and would act accordingly if it was thought necessary. The watering suggested as a remedy would be worse than the disease in some cases, and bring the roads down.

Mr. W. WARDLE mentioned that methods similar to those suggested for conveying water about mines had been tried, especially in South Wales.

Mr. TERRY gave an instance in which it had been done by means of travelling tanks, and said that he knew a colliery where pipes had been placed along the workings, but in about a month's time the perforations became clogged up and they were removed, but he believed modifications had since been made.

Mr. W. WARDLE said that two similar methods had been tried but eventually found to be impracticable, and were done away with.

Mr. E. J. BAILEY said they had tried the suggested plan at their collieries in South Wales, but it had not been a success.

The PRESIDENT remarked that the common theory was that coal-dust itself contained gas.

Mr. TERRY narrated his experience of a Welsh colliery some few days after an explosion which occurred in 1886. He and the manager were of opinion that the explosion was due to coal-dust. There happened to be an underground hauling-engine which stood in a recess very much higher than the engine itself. A boy was at work in close proximity, and

for convenience he had placed a small can of petroleum on the steam-chest. This very quickly evaporated, caused a burst of flame and ignited the coal-dust, of which there was a considerable quantity in consequence of the extremely dry nature of the coal. A terrible explosion was the result, about 75 lives being lost. Mr. Terry then described a method of watering mines by means of a small tank on wheels holding some 50 to 60 gallons, the whole tank and apparatus being about the size of an ordinary tub. At one end of the tub was a hollow spoked wheel whose hollow axis revolved in a gland and was connected with the water in the tank. The hollow wheel (an inverted Barber mill) revolved in a plane at right angles to the roadway, by gear wheels, and a pitch chain on the axle of the tub. By this means the water was thrown over the entire surface of the road, top, sides, and bottom, and from the velocity at which the water issued, due to the rapid rotation of the wheel, the water was broken into a fine spray which thoroughly moistened the whole surface of the roadway. The advantage of this machine was the absence of minute holes to clog, and that dirty water could be used as readily as clean water. The truck was used by attaching it to a train of tubs and running it once or twice daily along each roadway.

THE MASON COLLEGE.

The PRESIDENT mentioned that he understood the Mason College was about to be extended. He was not quite conversant with the details and negotiations, but he was under the impression that room was originally offered to the Institute: the opportunity, however, slipped by and the professors kindly allowed them to use the present room. Then, when the College was extended it was thought a room might be provided, and he was of opinion that now would be the time for the Secretary to see what could be done.

It was afterwards ascertained that the Institute could still have the use of the professors' room if the meetings were held at 5 p.m.

The meeting then terminated.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, DECEMBER 1ST, 1892.

MR. W. F. CLARK, PRESIDENT, IN THE CHAIR.

Upon the motion of the PRESIDENT it was unanimously resolved that a letter of condolence should be sent to the family of the late Mr. Henry J. Marten, M. Inst. C.E., who had been a member of the Institute for twenty-four years. Moreover, the deceased was an arbitrator for the South Staffordshire Mines Drainage Board, and had held a leading position in the district.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

It was shown by the minutes that the Council had postponed the Annual General Meeting until after the end of July, 1893, in order to bring the financial year of the Institute into line with that of the Federated Institution of Mining Engineers, and thus avoid several difficulties.

Mr. Edward Kidson, Bilston, and Mr. George Frederick Wynne, of Wrexham, were elected Ordinary Members.

Mr. W. FAIRLEY read the following "Practical Notes on the Geology of Wirral":—

PRACTICAL NOTES ON THE GEOLOGY OF WIRRAL.

By W. FAIRLEY.

Whilst the Trias or New Red Sandstone attains in Cheshire a total thickness of 3,000 feet, which is the greatest development of the formation in Britain, it does not exceed a thickness of 1,800 or 1,900 feet in the western part of the county, known as Wirral. The surface-geology very much resembles that of Cannock Chase, Rugeley, and the neighbourhood of Sutton Coldfield, nearly all the strata which are to be seen in passing through the peninsula being representative of some division of the Trias. A very large extent of the surface of the whole county is occupied by this formation. The pebble-beds of Wirral are very much like those of Cannock Chase, and after an examination of various specimens of the pebbles from the Bunter and Keuper of the district, Prof. T. G. Bonney concluded that many of the hard quartzites and quartzose rocks were identical with those found in Staffordshire, and was of opinion that they were derived from the same sources. He further said that "quartzite-pebbles identical with those in Staffordshire occur plentifully in the Upper Palæozoics of Southern Scotland." In a lecture delivered by Prof. Bonney, at Rugeley, in 1887, "On the Pebbles of Cannock Chase," he made out a very strong case for the hypothesis that the source of derivation of the Bunter pebbles was Scotland, where was to be found a mass of quartzite, which was not only to the naked eye precisely like the pebbles of Cannock Chase, but also corresponded in the general absence of fossils and the presence of minute minerals, the latter only discoverable by the use of the microscope. The remarkable similarity of some of the pebbles with certain of the rocks found in Scotland impelled him to attribute their origin to those rocks, and to conclude that they have been brought here by water. In Cheshire and Lancashire the pebble-beds are from 500 to 700 feet thick, and in Staffordshire from 100 to 300 feet.

I.—SYNOPTICAL TABLE SHOWING THE OCCURRENCE OF THE VARIOUS FORMATIONS IN WIRRAL.

System.	Name of Formation.	Locality where found and other Particulars.	Remarks.
POST-GLACIAL.	Beds of peat, stumps of trees in the position in which they grew, with silt, sand, and peat.	Exposed on the sea-coast, and in the marshes south of the Mersey. Submarine forest seen near Dove Point.	Thickness, 35 feet and upwards.
GLACIAL DEPOSITS.	Upper Drift Sand	East of Liverpool 10 feet thick	At Egremont, about 100 feet thick.
	Upper Boulder Clay.	Stiff brown clay, with boulders and small stones from the size of a pea to 6 feet in diameter. To be seen at West Kirby, Egremont, etc.	
	Middle Sands ...	From a mere parting up to 10 feet thick, and usually current-bedded. To be seen at West Kirby and Egremont.	
	Lower Boulder Clay.	Clay, with fragments of local rocks and small boulders and stones brought by ice from a great distance. Visible at West Kirby and Egremont.	
	Lower Drift Sand	Originated from the denudation of the Triassic strata.	
TRIAS. KEUPER.	Red Marl and Water-stones.	100 feet thick in Liverpool. Exposed in the cast of Storeton Quarries, and on Oxton Hill.	Estimated thickness at Bidston, 1,800 to 1,900 feet.
	Keuper Sandstone	To be seen at West Kirby and Heswell. Although estimated to be only 100 feet thick, it was found to be 170 feet thick in the Liscard borehole, and in the heading at Flaybrick Well it was found nearly 200 feet thick. Produces good building-stone at Flaybrick, Bidston, Oxton, and Storeton.	
TRIAS. BUNTER.	Upper Soft Sandstone	Estimated to be 550 feet thick; 404 feet in the Liscard borehole.	
	Upper Pebble Beds	These strata were passed through in the Mersey Tunnel. The estimated thickness is 415 feet.	
	Lower Pebble Beds	Exposed on the banks of the Dee, etc. The estimated thickness is 611 feet.	
PERMIAN.	Lower Soft Sandstone	Supposed to represent the Permian. Exposed at Burton Point. Thickness perhaps 400 feet.	
CARBONIFEROUS.	Coal-measures ...	These strata are exposed at the surface at Ness, and found to extend 5½ miles south of that, namely, to Griffe's Farm, Queen's Ferry, and Lloyd's Farm, where they are covered over with 50 to 60 feet of sand. At Neston there are numerous beds of workable coal, semi-bituminous in character. The direction of dip varies much, but will average about north.	Thickness unascertained.

Mr. G. H. Morton, F.G.S., in his excellent work on *The Geology of the Country around Liverpool* gives many details of the stratigraphy at various places in Wirral, and a perusal of this book, together with his own knowledge of the neighbourhood, has enabled the writer to submit the annexed synopsis (Table I.) of the geology of the district.

At different horizons of the Triassic, which is here the main system of rocks, very good building-stone is obtained, some being worked from the upper and lower pebble-beds, and some from the Keuper Sandstone. Mr. Morton says that the beds known as the "Lower Soft Sandstone may be regarded as belonging to the Permian."

The following particulars of the lie of the Coal-measures and of mining operations will perhaps be of interest.

Fig. 3, Plate XVI., shows how the coal-seams lie at Old Ness and Neston collieries.

Although the Two-feet coal appears to be regarded by some of the miners at Neston as the lowest seam, other beds of coal have been found, by putting down boreholes on the crop of the measures. The sections in Figs. 2 and 3, Plate XVI., give the position of some of these as accurately as the writer has been able to ascertain them.

II.—Section of Strata at No. 23 Pit from the Six-feet to the Seven-feet Seam.

	Ft.	Ins.
Six-feet coal	6	0
Warren	1	6
Dummil	15	0
Metal	16	6
Stone roof	54	0
Clod and coal	3	0
Five-feet coal	4	3
Warren	1	6
Dummil	15	0
White stone	6	0
Bur	9	6
Black linsly	8	0
Red stone	5	0
Linsly	7	0
White greet	4	0
Grey greet	4	0
Flag	15	0
Grey stone	4	0
Grey bass	6	0
Black bass	4	0
Seven-feet coal	7	0
Total	196	3

III.—Section of Strata Bored through at B, Fig. 1, Plate XVI., to the Crop of No. 29 Pit, below the Two-feet Coal.

	Ft	Ins.
Soil	1	0
Marl	27	0
Gravel and sand	6	4
Black bass	2	0
Fireclay	19	6
Dark blue metal	15	9
White rock	0	10
Linsly	7	7
White rock	1	6
Brown rock	3	3
White rock	0	6
Brown rock	33	1
Coal	0	2
White rock	10	6
Linsly	2	6
White rock	13	0
Linsly	5	0
Total	149	6

IV.—Section of Strata passed through in a Borehole below the Two-feet Coal in No. 8 Pit, Ness Colliery.

	Ft.	Ins.
Fireclay	19	0
Grey shale	8	0
Linsly	2	4
White rock, with soft partings 2 to 4 inches thick	35	3
Coal	0	5
White rock	2	0
Coal	0	8
White rock	0	4
Blue metal	0	8
White rock	6	0
Linsly, with iron bands	10	4
White rock	22	0
Blue metal	15	0
White rock	3	0
Blue metal	0	6
Linsly	4	6
Blue metal	0	6
Linsly	12	6
Rock	5	0
Linsly	3	0
Rock	10	0
Total	161	0

V.—SECTION OF STRATA BORED THROUGH AT A, FIG. 1, PLATE XVI.

	Depths from Surface. Ft.	Ins.	Thickness of Seams of Coal. Ft.	Ins.
Sand and gravel	52	6	—	
Coal	227	1	1	5
"	232	11½	5	4½
"	238	7	1	0
"	239	1	0	4
"	241	3	2	0
"	258	3	0	2
"	356	6	0	6
"	441	0	3	0
"	498	6	3	0
"	543	6	4	6
"	546	4	1	4
"	551	0	3	3
"	586	10	4	3
Total			30	1½

VI.—SECTION OF STRATA BORED THROUGH AT E, FIG. 1, PLATE XVI.

	Depth from Surface to Bottom of Seams. Ft.	Ins.	Thickness of Seams of Coal. Ft.	Ins.
Sand and gravel	67	6	—	
Hollin coal	190	6	1	3
Brassy coal...	234	8	3	0
Rough coal...	238	7	0	10
Rough coal...	256	9	1	0
Main coal	377	11	9	0
Woodpit coal	457	3	0	2
"	459	0	0	5
Four-feet coal	498	5	1	2
Yard or Cannel coal ...	524	1	0	8
Wall and Bench coal ...	612	5	1	3
Total ...			18	9

VII.—SECTION OF STRATA BORED THROUGH AT F, FIG 1, PLATE XVI.

	Depths from Surface. Ft.	Ins.
Sand and gravel	73	6
Stiff brown pinnel	79	6
Red sandstone	953	0
Red shale	966	0

The coal generally is a fair house coal, but much of the slack is used for steam purposes.

The coal-field is somewhat faulted and the strike of the measures is very undulating. The Coal-measures are faulted against the Lower Soft Sandstone at Ness colliery, and at Neston, a mile farther north, against the Pebble Beds.

Coal-mining has been carried on for about 150 years, although never on a very large scale. The underground workings in the Six-feet and Five-feet coals have been extended in a north-westerly direction as far as 1¾ miles beneath the River Dee, and at the present time the workings in the Seven-feet coal have reached a distance of more than 1½ miles under the sea. The Wirral Colliery Company are now working about 100,000 tons of coal per annum.

The water from the Dee has occasionally in past years been a difficulty in mining, and "crownings-in" have occurred; these appear to have all taken place in the Six-feet coal. At the present time there is no difficulty with the water, which is well under command, the company having erected not long ago a very large pumping-plant. The mine water is very salt.

One of the questions the writer had before him in making these notes was as to the probability of finding coal east and north of the abandoned and the existing coal-mines; and in considering the matter he was somewhat at a loss to understand why a search had never been made on the eastern side of the present limits of coal-mining operations. Circumstances are much in favour of the probability of finding coal at a workable depth on the land-side, that is, eastward of the line B C marked on Fig. 1, Plate XVI., which represented the Great Downthrow Fault; indeed it is recorded that coal has been found at a depth of 510 feet below the surface at Shotwick, where the surface formation is the Lower Soft Sandstone or Permian.

As regards Bidston, where a borehole, the position of which is marked D on Fig. 1, Plate XVI., was commenced some time ago in search of coal, Mr. Morton thinks that 1,900 feet of New Red strata will have to be passed through before Coal-measures are reached, and seeing that the Lower Soft Sandstone or Permian has been touched at a depth of 1,400 feet it shows that his estimate of the thickness of the New Red deposits is a very accurate one.

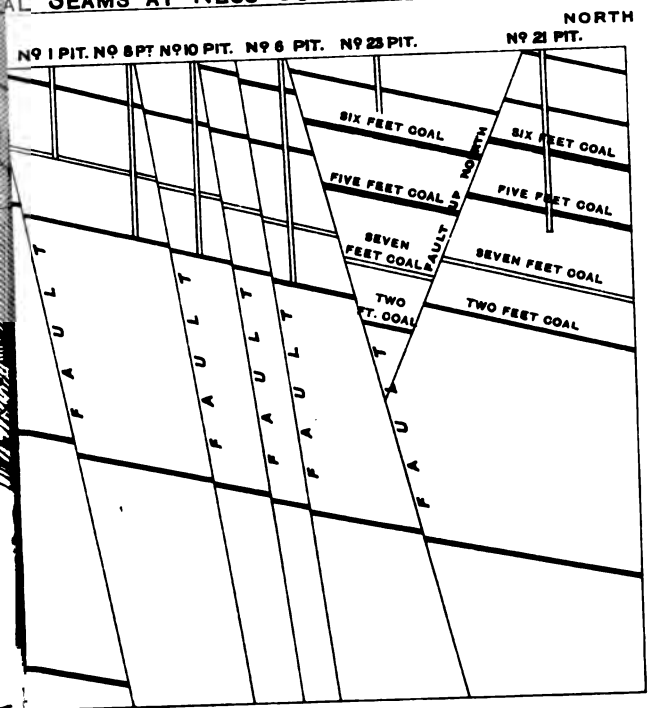
With a view of endeavouring to form as good an opinion as possible on this question Fig. 3, Plate XVI., has been drawn to scale from some of the sections enumerated, and from the (geologically coloured) map of Wirral, and although on the whole it is only a projection, yet on many points, it is substantially correct.

Seeing that the Lower Soft Sandstone or Permian is faulted against the Coal-measures south of Neston, it is very probable that the Coal-measures east of the fault about Ness will be found within a depth of 500 or 600 feet.

From the section of strata shown in Fig. 3, Plate XVI., it seems not improbable that the Coal-measures north of Neston may be reached within

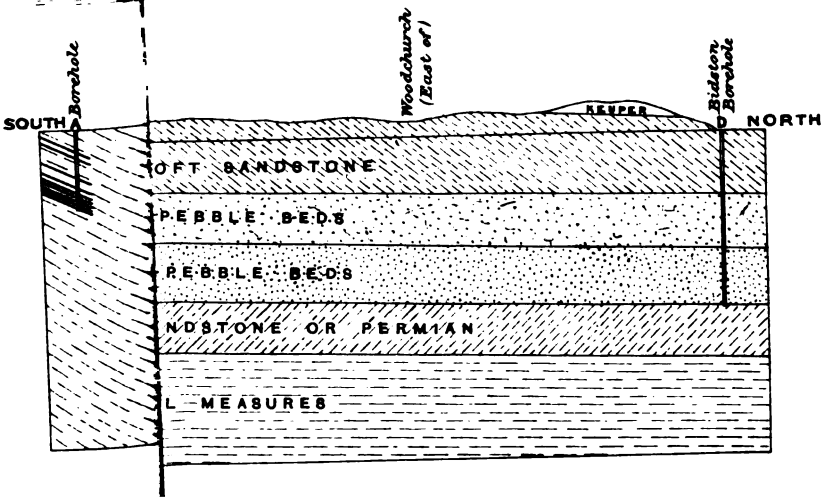
FIG. 2.

AL SEAMS AT NESS COLLIERIES.



tal Scale 400 Feet to 1 Inch.
Scale 300 Feet to 1 Inch

EE, NEAR QUEEN'S FERRY,
ALONG THE LINE A. B. C. D. ON FIG. 1.



a depth of 1,200 feet from the surface, and that at Bidston the depth is likely to be between 1,800 and 1,900 feet. It likewise seems fairly probable that the Coal-measures lie under the greater part of the area of the Hundred of Wirral, and extend under the Mersey to Liverpool, the nearest coal strata to which are said to have been found under Croxteth Hall.

Mr. SOPWITH said that Mr. Fairley's paper was a valuable one, as, apart from the local details, which would form a useful reference, there was, to some extent, an apparent analogy between the section shown and that which existed on the eastern side of the boundary fault near No. 5 pit of the Cannock Chase colliery. Here they had passed through, in a trial heading, about 90 yards of red marls, clays, and sandstones, overlying the Coal-measures, and pitching down at inclinations of 45 to 70 degs., but in a most confused way. The Bunter beds would, he believed, be found abutting against them in a regular and horizontal position, and much in the same way as shown in the Wirral section (Fig. 3, Plate XVI.), although in the former case individual beds, and even whole horizons of strata of the Coal-measures were missing, as though they had slipped down more quickly than others. The study of the red beds was an interesting one, as they might easily be confounded with Permian strata, and indeed he had not been able clearly to correlate the beds in the Cannock Chase section with those of Walsall Wood and elsewhere, though he felt assured they were corresponding strata. As to the red clays, and which were found on the east and west side of the northern part of the field, and also in some parts of the southern portion, there was no doubt as to their being similar to the Upper Coal-measures as found in Shropshire, North Wales, Cheshire, and elsewhere, and the relation of which to the Lower Coal-measures had been clearly established by Messrs. Evans, Binney, and others. He alluded to this matter as there were Permian measures marked on the section, and it would be interesting to know whether these were really Permian or Upper Coal-measures; or again, whether red upper measures might not also exist. He would ask whether there was a large quantity of water in the gravel or conglomerate beds? At Cannock Chase they expected to meet with large feeders when they struck the Bunter conglomerate.

Mr. W. B. SCOTT enquired what was the dip of the New Red Sandstone and the Carboniferous formations?

Mr. J. WILLIAMSON said at the Cannock and Rugeley pits the depth was about 60 yards to the bottom of the gravel beds, and then the clays

—which he thought were the red clays—came next, and they had only proceeded some 10 or 12 yards more when they struck the Coal-measures.

Mr. SCOTT wished to know if they were conformable?

Mr. WILLIAMSON, in reply, intimated that they were.

Mr. SCOTT said that from the various undulations of the surface one might be led to believe these measures unconformable. There might have been a considerable undulation of the surface, and if a shaft was sunk at that particular point it might be found that the coal was not conformable.

Mr. SOPWITH mentioned that it was interesting to note that there appeared to be no faulting in the heading at Cannock Chase. The strata appeared to have bent over and fallen away in a gigantic landslip. [Mr. Sopwith pointed out some peculiarities of the trial section, and used the Wirral section to illustrate his remarks.] In doing so he explained the general evidence for the assumption that the measures were thrown down for 800 to 1,000 yards on the eastern side of the boundary fault at Cannock Chase.

Mr. SCOTT understood that the red rocks overlie the Coal-measures in the Denbighshire district, except in the case of the covering of the glacial drift, but it was found there that a similar description of red sandstone was conformable to a very considerable extent with the grey Coal-measures lying below.

Mr. GLENNIE related some particulars of the crowning-in of the sea, on the Dee, about 180 yards from the shore. He mentioned that three good seams of coal were being worked, drifting from one seam to another at about 1 in 3 till a point within 30 yards of the bottom of the river, and the water was found to come in pretty freely. Ultimately the river broke in and the very valuable colliery was flooded and still remains so.

Mr. SOPWITH moved that the thanks of the meeting be given to Mr. Fairley for his paper.

Mr. W. F. CLARK, in seconding the resolution, hoped that this paper would stimulate some of their members to look more closely into the matters referred to, and these he was sure would prove interesting to the Institute. Mr. Sopwith, he hoped—seeing that he understood the subject so well, especially that of the eastern fault—would try and see his way to submit a paper on the question.

The vote of thanks having been accorded the meeting terminated.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, FEBRUARY 11TH, 1893.

MR. J. B. SIMPSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 28th and February 11th.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

Mr. THOMAS ALEXANDER ALLAN, Consulting Mining Engineer, Brightlands, Richmond Hill, Surrey.

Mr. THOMAS BREAKELL, Mining Engineer, 92, Denmark Road, Greenheys, Manchester.

Mr. WALLACE THORNEYCROFT, Mining Engineer, 6, Dixon Street, Glasgow.

Mr. HENRY THOMAS WALES, Mining Engineer, 104, St. Mary Street, Cardiff.

ASSOCIATE MEMBERS—

Mr. JAMES ERNEST BLENKIRON, Mining Engineer, West House, Arkengarthdale, Richmond, Yorkshire.

Mr. J. CARTMEL RIDLEY, Steel Manufacturer, 3, Summerhill Grove, Newcastle-upon-Tyne.

ASSOCIATE—

Mr. JOHN SPRY, Surveyor, Murton Colliery, *via* Sunderland.

The following gentlemen were nominated for election :—

MEMBERS—

Mr. M. W. BARKER, P.O. Box 1,463, Johannesburg, Transvaal.

Mr. HENRY B. BUNKELL, P. O. Box 962, Johannesburg, Transvaal.

Mr. WILLIAM YOUNG CAMPBELL, Mining Engineer, etc., P.O. Box 357, Johannesburg, Transvaal.

Mr. WILLIAM CHARLTON, Mining Engineer, Linares, Provincia de Jaen, Spain.

Mr. SHERARD OSBORN COWPER-COLES, Manager, London Metallurgical Company, Limited, 80, Turnmill Street, London, E.C.

Mr. JAMES HUBERT DANGAR, Camborne, Cornwall.

Mr. J. HUBERT DAVIES, Electrical Engineer, P.O. Box 455, Johannesburg, Transvaal.

Mr. ALFRED DUMAT, Mechanical and Railway Engineer, 1, Loop Street, Pietermaritzburg, Natal.

Mr. E. W. EVANS, Mining Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. LOUIS FARAGHER, Mine Agent, Cape Copper Co., Ld., Ookiep, Namaqualand, South Africa.

Mr. ALBERT H. HALDER, Consulting Engineer, Pietersburg, Transvaal.

Mr. J. KERR HOULGATE, Mining Engineer, 69, Lowther Street, Whitehaven.

Mr. JOHN ARTHUR JONES, Mining Engineer and Analytical Chemist, Gijon, Asturias, Spain.

Mr. JOHN O'GORMAN LALOR, Mining Engineer and Metallurgist, P.O. Box 357, Johannesburg, Transvaal.

Mr. HENRY LAKIN LAWRENCE, Mining Engineer, Mines de Pierrefitte, Pierrefitte-Nestalas, Hautes Pyrénées, France.

Mr. RICHARD A. D. LIEBERT, Mechanical Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. R. H. LONGBOTHAM, Mining Engineer, Westgate, Wakefield.

Mr. DAVID ALEXANDER LOUIS, Metallurgical and Mining Engineer, 77, Shirland Gardens, London, W.

Mr. JOHN S. MACARTHUR, Metallurgist, 12, Knowe Terrace, Pollokshields, Glasgow.

Mr. JOHN HODGSON NICHOLSON, Mining Engineer, Seaton Delaval Colliery, Northumberland.

Mr. FRANCIS DANIEL PETER, Mining Engineer, Greymouth, New Zealand.

Mr. JOHN GUNSEN SELKIRK, Mining Engineer, Dalton-in-Furness.

Mr. A. HUMBOLDT SEXTON, Professor of Metallurgy, Metallurgical Department, Andersonian Buildings, 204, George Street, Glasgow.

Mr. CHARLES LIDDELL SIMPSON, Mechanical Engineer, Engine Works, Grosvenor Road, Pimlico, London.

Mr. ARTHUR JAMES STEVENS, Mechanical Engineer, Uskside Ironworks, Newport, Monmouthshire.

Mr. W. HENWOOD TRELEASE, Chief Agent of the Pestarena United G. M. Co., Ld., Pestarena, Vall'Anzasca, Novara, Italy.

ASSOCIATE—

Mr. JOSEPH THOMPSON, Overman, 38, Church Street, Murton Colliery.

Mr. ROBERT T. MOORE read the following paper on "Joseph Moore's Hydraulic Pumping Arrangement":—

JOSEPH MOORE'S HYDRAULIC PUMPING ARRANGEMENT.

By ROBT. THOS. MOORE.

The problem of how best to drain our mines is one of the greatest interest to an institution such as this. It would be easy to dilate upon the inconvenience of pump-rods and upon the expensive nature of their up-keep, and also upon the destructive and expensive nature of break-downs, when the full power of the engine is continued without resistance. This, however, is so well known to the members that it is unnecessary to take up the time by discussing it.

But it may be stated that these difficulties have, in a great measure, set men thinking as to whether they could not dispense with pump-rods altogether; and the direction that this search for a new method so far has taken has been to place the steam engine at the bottom of the pit or in the mine, carrying the steam from the surface or erecting boilers underground. Within the last few years electricity, hydraulic power, and other expedients have been tried with varying degrees of success.

The arrangement now to be described is a form of hydraulic pumping. It is at present extensively used in Scottish mines, and it is thought that a description of it may be of interest to members of the Institute.

The arrangement enables two columns of water to be substituted for the ordinary pump-rods connecting the steam engine with the pump, which may be placed any distance from each other. Advantage is taken of the fact that water is practically incompressible, and that if a pipe of any length is filled with water a plunger at one end will, if pushed forward, propel a plunger placed at the other end in the same direction. If there were two pipes and two plungers there would be a reciprocating motion.

The action will readily be seen from Fig. 1, Plate XVII., which is not drawn to scale, but is merely for the purpose of illustrating the arrangement.

At the steam engine is a hydraulic cylinder *a b*, in which works a piston *p* called the power ram, and this is moved by a crank driven by the steam engine.

At the pump is a cylinder *c d*, exactly the same as that at the steam engine and in this is a piston *q* also called a power-ram. This power-ram is attached to the plunger *r* of a double-acting pump.

A pipe *e* connects the end *a* of the power-cylinder at the engine with one end *d* of the power-cylinder at the pump. A similar pipe *f* connects the other end *b* of the power-cylinder at the engine with the end *c* of the cylinder at the pump.

When both cylinders and pipes are filled with water, and the piston *p* is moved by the engine from *a* towards *b*, the water in the cylinder is forced through the pipe *f* into the *c* end of the cylinder *c d* at the pump, and the power-piston *q* is moved from *c* towards *d*.

In like manner when the piston at the engine moves from *b* towards *a*, that at the pump moves from *d* towards *c*, carrying the pump with it. In this way the pump is moved backwards and forwards in the same way as if there had been a direct connexion with rods between the steam engine and the pump.

In order to provide for leakages a tank is placed above the level of the highest point of the power-pipes with pipes from it to the power-pipes *e f*. On the end of each pipe is a valve opening inwards, so that when the engine moves the power-ram *p* from *b* to *a*, water may run from the tank into the pipe *f*. When it moves from *a* to *b*, water may run into *e*.

An arrangement of this kind will not work satisfactorily unless there are means for regulating the stroke of the pump. For example, if by any cause the piston when being moved from *d* to *c* were to stop before completing its stroke the succeeding stroke from *c* to *d* would be too long, and the ram would be driven against the end of the pump and do damage. To obviate this, a case with two small valves *j k* is placed at the power-rams with pipes *g h* connecting the power-pipes *e* and *f*. Attached to these valves are levers *l* and *m* which work thus:—

When the piston passes the ordinary stroke, the tappet *s* strikes the lever *m* which opens the valve *j*, and the compressed water passes from the column *f* through the opened valve *j* lifting and passing through the valve *k* and running into the column *e*, thus taking the pressure off the power-piston and stopping it. In the next stroke from *d* to *c* the water is stopped by the valve *k*, and the piston makes the full stroke, stopping before the tappet reaches the lever.

It will thus be seen that the adjustments are automatic, and in practice they are found to be very complete.

Having described the principle of the arrangement, the following

description of a plant at the Linlithgow Oil Company's Champfleurie mines, will show an application of it.

The steam engine (Figs. 2 and 3, Plate XVII.), is placed on the surface, 50 feet from the mouth of the mine which dips from the surface at an inclination of 1 in 3: the pump is placed 500 yards from the surface and throws the water 83 fathoms vertically.

The engine is high-pressure, with a cylinder 20 inches in diameter and 4 feet stroke, and is geared to the pumping crank-shaft at the rate of 6 to 1, the small wheel being 20 inches in diameter and the large wheel 10 feet in diameter. The pump is double-acting, 12 inches in diameter and 4 feet stroke. It is driven 8, 4 feet strokes, and discharges 300 gallons per minute. It has been in operation for two years.

The surface power-rams are two solid steel plungers *b* and *c*, 6 inches in diameter and 4 feet stroke, and are worked by a connecting-rod *d* from the crank *e*. Malleable iron power-pipes *f* and *g*, $2\frac{3}{4}$ inches bore and $\frac{3}{8}$ inch thick, pass from the ends of the power-ram casings to the power-rams at the pump. A pipe *j*, $\frac{3}{4}$ inch in diameter reaches from the supply tank to the valve-box *k*, with two valves 1 inch in diameter opening inwards to the power-pipes. A pipe *l*, $\frac{3}{4}$ inch in diameter connects the top of one valve with the power-pipe *f*, and another *w* connects the other with the power-pipe *g* at the pump.

The mine pump (Figs. 4 and 5, Plate XVII.) is horizontal and consists of two rams *m* and *n*, 12 inches in diameter and 4 feet stroke, face to face, and connected to a cross-head *s*. The power-rams *o o* and *p p*, each 4 inches diameter, are placed alongside of each pump-plunger, and are connected to the cross-head.

The power-rams *o o* are connected with each other by the pipe *q*, and are connected with the surface power-ram by the power-pipe.

In like manner the power-rams *p p* are connected together and connected with the surface power-ram by the power-pipe.

The tappet *s* on the cross-head is so placed that when the pump has come to near one end it comes into contact with the levers *t* or *u*, and one of the equalizing valves in the casting *v* is opened, and the water passes from one power-pipe to the other, and the plunger stops.

The maximum pressure of the water in the power-pipes is about 2,000 lbs. per square inch.

At Balquhatstone colliery, Slamannan, there are two sets of double-acting 12 inches pumps worked by one geared engine, raising 600 gallons a minute from the bottom of a vertical shaft 65 fathoms deep. The

driving cranks for the surface power-rams are fixed at right angles, so that the engine is balanced. Either pump can be worked independently of the other by disconnecting the power-rams at the engine, so that it forms a duplicate plant. This is found to be a very good arrangement and several installations have been fitted up on this plan.

This system has been applied for sinking. Figs. 6, 7, 8, and 9, Plate XVIII., show a sinking pump which was used for raising 300 to 500 gallons per minute during the sinking of a shaft 100 fathoms deep.

It will be seen from the drawing that the pumps slide in wooden guides like a cage, and the whole arrangement of pumps, power-pipes, and rising column is carried by iron rods from a hydraulic ram fixed over the pit. The plungers, which are hollow, are placed vertically, and the one plunger is half the area of the other, so that the pump is double-acting. The lower pump plunger is 18 inches in diameter and has a clack inside of it. At the bottom of the plunger-casing is a clack-piece, and below that is the suction.

The upper plunger is 12¾ inches in diameter.

The upper casing is connected to the rising main, and the lower one is connected with the upper by four bolts.

The power-rams work in the same way as in the horizontal pump already described.

The following is the action of the pump:—When the plungers ascend, the lower plunger lifts a quantity of water represented by a plunger 18 inches in diameter and it passes up through the lower valve, the valve inside the plunger remaining shut. When the plungers descend, the valve at the bottom shuts, while the valve in the plunger opens, allowing the whole water from the 18 inches plunger to pass through it, but as the 12 inches plunger is descending out of the casing at the same moment, only half of the water ascends to the surface and the other half fills the space occupied by the 12 inches plunger. When the plunger ascends again, the 12 inches plunger discharges the water into the rising main.

Immediately above the upper barrel is an air-vessel, 14 feet long, made of malleable iron. The water passes up a central pipe which dips down from the top of the air-vessel, and it is the annular space round this central pipe which forms the air-space, the central pipe communicating at the top with the rising main.

A cup and small discharge-pipe are provided for receiving and at convenient intervals discharging any sediment deposited from the ascension pipe.

The rising main is made of malleable iron, in 24 feet lengths, and having cast-iron flanges riveted to them. The joints are spigot and faucet, and are made with a ring of gutta-percha, $\frac{3}{8}$ inch in diameter.

The hydraulic ram is worked with a small steam engine, and raises and lowers the whole pumps and columns. The lever which works this engine stops the main engine on the surface, and opens a valve communicating with the power-pipes, so as to let off the pressure due to their sliding into the sleeve-pipes when the pump is raised.

The upper two lengths of the rods are provided with holes into which a key is put for the plunger of the ram to press against.

Attached to the girder which supports the ram are two rods *a a* (Figs. 10 and 11, Plate XVIII.) of the same strength as the main rods, carrying a cross-head *b*, with recesses like a boring tool for catching the heads of the rods, which have a shoulder made to fit it. When the ram has run its full length this is put under the rods, and the whole weight of pipes, etc., rested upon it. A new length of rods is put in, and the ram is run out until it comes in contact with the key. The temporary rest is then removed and the ram is ready for further lowering.

On the top of the rising column is placed a "hogger" of sufficient length to allow the water to fall into the discharge drain, and the power-pipes work in stuffing boxes *l m*.

The arrangement for changing the upper clack is rather peculiar. The smaller plunger is carried down into the middle of the larger one as shown in the drawing, and at Fig. 14, Plate XVIII., and terminates in a recess in which works the T-shaped head of the clack. When it is in operation the lid has free room to move up and down without check. When the clack is to be shifted the column of water is run off, the pump raised to the top of its stroke, and the upper plunger disconnected from the lower one and suspended by two links. The lower plunger is then lowered down. The clack-lid remains hung by the T-head on to the inner plunger; and as the lower plunger descends is left outside, when it is drawn out of the slot and renewed. The lower plunger is then raised and the two connected, the clack having then room to work as before.

This sinking-pump was erected in a gold-mine in Nevada, but so far all the pumps erected in this country have been horizontal, and fixed either at the bottom of the shaft or in the workings.

The steam engines for driving these pumps may be either direct-acting or geared, as may be found most convenient. In most of those erected, the engines are geared in the proportion of 6 to 1, so as not to drive the power-rams more than 8 strokes per minute.

A pump worked on this system gave a useful effect of 68 per cent. of the indicated diagram of the steam engine with an inclined distance of 800 yards between the engine and pump.

Another pump gave over 66 per cent. of efficiency. These results compare very favourably with electricity and compressed air.

Some of the advantages of the system are :—The large percentage of useful effect got from it. The engine and pumps can be put away from the shaft, leaving the pit-head and pit-bottom unobstructed and the shafts clear of any moving pitwork. The saving of room will be apparent when it is stated that with the Balquhatstone pump there are only four lines of 3½ inches pipes in the shaft to drive pumps throwing 600 gallons of water a minute, 65 fathoms vertical. In inclined and dip workings the power-pipes may be led round any number of bends. The parts underground are of the simplest description and not liable to get out of order, and there is no need for an attendant.

Some of the pumps have worked covered with water. Another advantage, and a very great one, is that the small amount of room taken up by the apparatus facilitates the erection of duplicate arrangements, whereby, should any breakdown take place, the pumping could be continued by one of the engines until the repairs are completed.

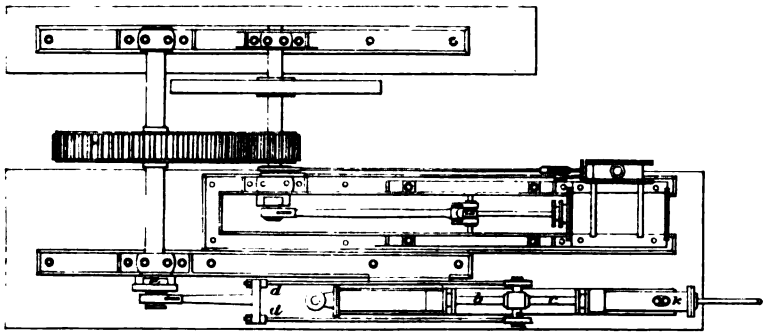
As regards cost, perhaps the simplest way will be to quote an offer made to supply a colliery with plant for raising 400 gallons of water per minute from the bottom of a shaft 150 fathoms deep. Boiler pressure 100 lbs. per square inch.

The water to be raised in two 75 fathoms lifts, a double-acting pump with plungers 14 inches in diameter, 5 feet stroke, to be put at the pit bottom to throw half-way up the shaft, at which point another pump of exactly the same size is placed to throw the water to the surface.

Engine—	
Compound high-pressure cylinder, 18 inches in diameter Low-pressure cylinder, 30 inches in diameter ... ... Stroke, 5 feet ... ... Gearing, 6 to 1, large wheel being 12 feet in diameter ...	£900
Two sets of pumps each.	
Surface power-rams, 6¾ inches in diameter ... ... Stroke, 5 feet ... ... Pumps, double-acting, 14 inches in diameter ... ... Power-rams (two pairs each), 4½ inches in diameter... Stroke, 5 feet £1,100	
Power-pipes, 3½ inches bore, $\frac{7}{16}$ inch thick, say 3,000 feet at 3s. 6d.	£525
Total cost	£2,525

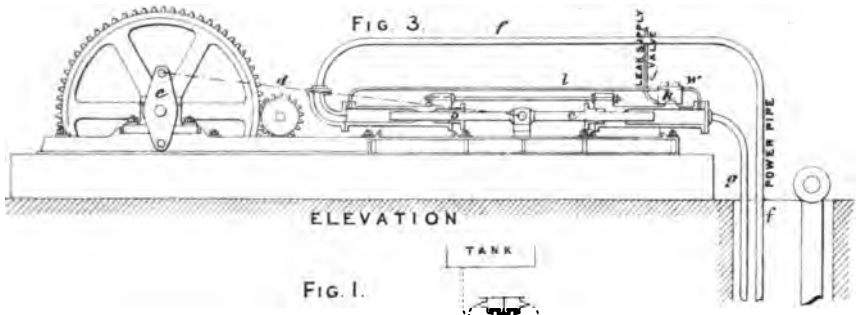
To illustrate Mr. R. T. Moore's Paper on "Joseph Moore's Hydraulic Pumping Arrangement."

FIG. 2



PLAN

FIG. 3.



ELEVATION

FIG. 1.

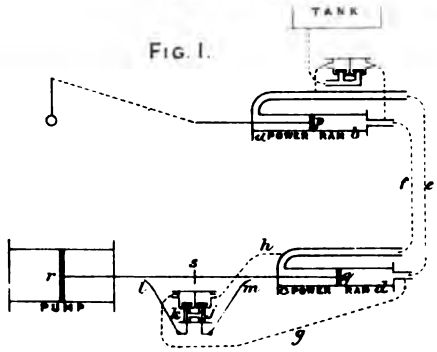
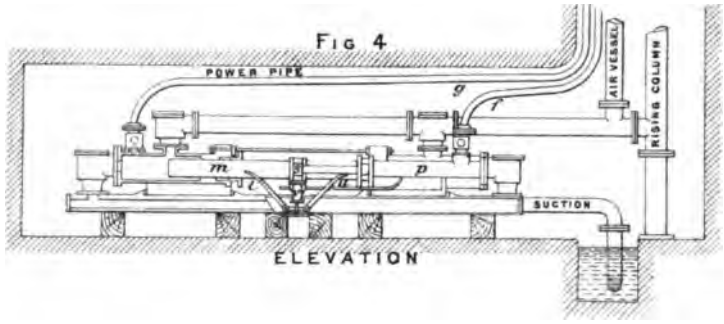
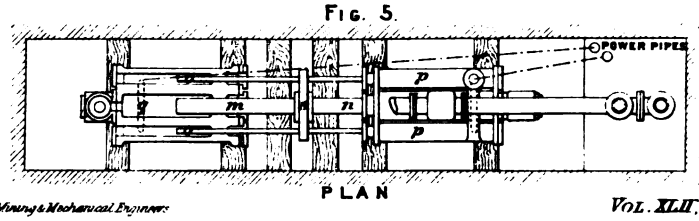


FIG 4



ELEVATION

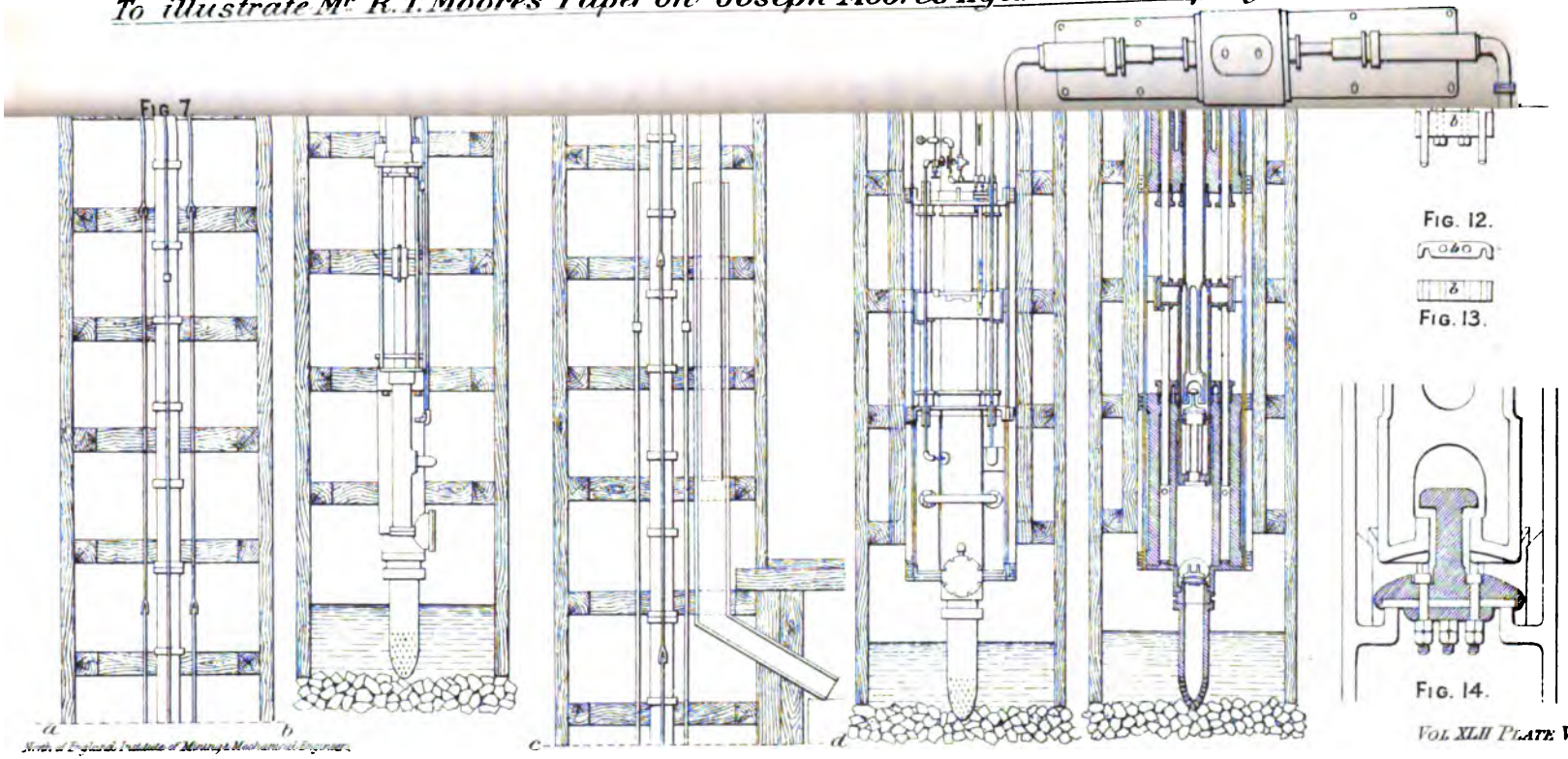
FIG. 5.



PLAN

Federated Institution of Mining Engineers.
Transactions 1892-93

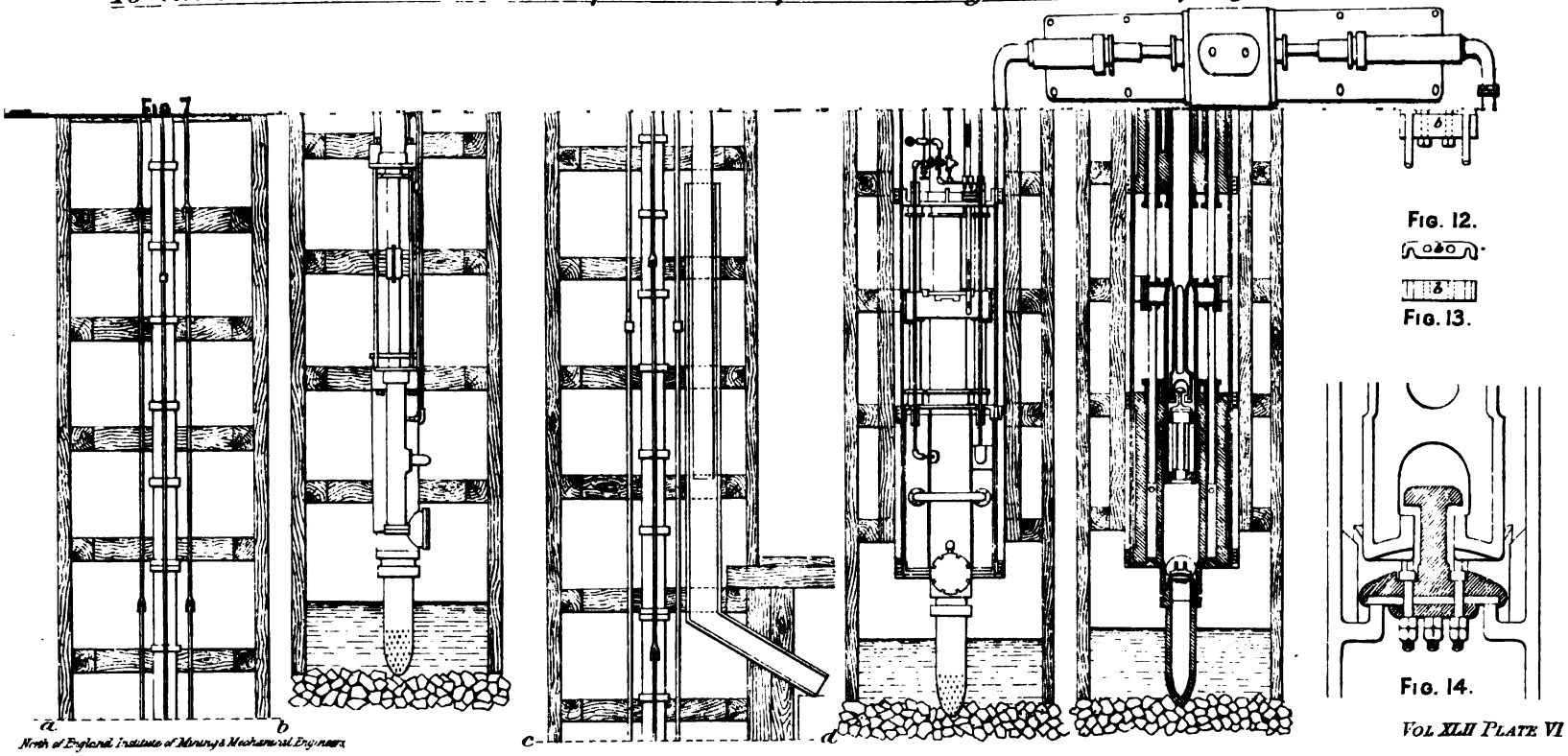
To illustrate Mr. R. T. Moore's Paper on "Joseph Moore's Hydraulic Pumping Arrangement."



North of England Institute of Mining & Mechanical Engineers.
Transactions 1892-93.

Andw Reid Sons & Co Lithos Newcastle

To illustrate Mr. R. T. Moore's Paper on "Joseph Moore's Hydraulic Pumping Arrangement."



Mr. C. C. LEACH asked what advantages the Moore pump had as compared with the ordinary hydraulic pump?

Mr. R. T. MOORE said one advantage was that the water in the pipes was never changed, and consequently there was no difficulty as to working with clean water. Again, in the ordinary hydraulic pump some form of valve was required to admit the water alternately into each end of the power-cylinder, while in this pump there were no valves; and the arrangements underground were very much simpler than was possible with the ordinary hydraulic pump, which was practically an engine working underground.

Mr. H. LAWRENCE said one great advantage accruing from this system of pumping was that it was very suitable for placing at the bottom of a shaft where there was liability of being drowned out, because it would still work unless the valve arrangement went wrong. The system of the ram pump was not in any way different from what was otherwise in use at the present time. The novelty consisted, to a large extent, in having two pipes filled with water, which enabled them to lead the power whither they liked, but he thought there must be a large loss by friction in the moving of the water in the pipes. They all knew that it took a very much larger power to put a body in motion than to keep it in motion, and, although the writer stated that he got 68 per cent. of useful effect, that was not a very high percentage for an economical pump. Then, again, in such instances as the new pumping arrangements now being erected at the Wallsend collieries, he was afraid that as an engineer he could not advise its use for a large pumping-plant, but for small depths, and for the uses referred to in the paper he dared say it would work very well. As to the saving of space in the shaft, he did not know where the special advantage arose in this system, inasmuch as two pipes were put down the pit for the motor, but there must be another, which was not shown, for the delivery of water to bank. So that they must have three, nay, he thought he had even seen four pipes; and if they placed an ordinary direct-acting pump down the pit they would only have one pipe, which, he thought, was an advantage, as it would have very much less friction to contend with. The system described was deemed to be very applicable to sinking shafts, because it could be moved up and down in stages as the water was lowered, and the applications mentioned in the paper verified that assumption. There was another point, but he supposed they were all subject to that, viz., the question of very deep pits, where 300 or 400 lbs. per square inch would represent the pressure on these pipes, whether in such cases a very much larger amount of repair would not be required;

by having so many pipes there would be much greater risk of breakages, and he did not grasp exactly how Mr. Moore proposed to work with one pump in case anything went wrong with one of the pipes.

Mr. W. C. BLACKETT said there were several points which appeared to require a little elucidation. The writer opened the paper by saying it would be easy to dilate upon the inconvenience of pump-rods, and upon the great cost of their maintenance, and also upon the destructive and expensive nature of any accident; he then proceeded to describe the Moore hydraulic pump, thus suggesting that it was intended to do away with pump-rods, and at the same time to have equally efficient apparatus, but later in the paper he mentioned that a pump working on this system gave a useful effect of 68 per cent.; was it meant to infer that this system, with 68 per cent., was superior to the ordinary pump-rods in useful effect?

Mr. A. L. STEAVENSON said he had received from Mr. Joseph Moore copies of papers which he had read descriptive of his invention. It appeared to be a very useful pump, and of very good design; in fact, he had referred to it in the paper he recently read before this Institute on the subject of the different methods of power transmission. For pumping out of a shaft, however, he should still adhere to the old fashion; but there were many collieries where they could not use the ordinary pumping-plant with spears in the shaft, and in such cases nothing could possibly be better than Mr. Moore's arrangement, especially if they knew the volume of water to be pumped, and that the feeder did not increase or alter from time to time. In these cases it would be difficult to increase or duplicate the pumping-plant. The appliance seemed most ingenious, and under certain circumstances would do work which no other appliance could perform. He suggested that the naming of one or two parts of the pump might be altered. Reference was made to the piston or ram—but a piston is not a ram. He would have preferred to call it ram or plunger, for if they used the words indiscriminately they must add double-acting, whereas, if they kept them distinct one meant single and the other double-acting. Had the writer at any time tested the useful effect? Had he measured the water pumped as compared with the work done by the steam in the engine?

Mr. R. T. MOORE said the work done in raising water (as measured by the height the water was lifted and the water pumped) was 68 per cent. of the indicated horse-power of the steam engine. With regard to the alternate wording ram or piston, this was only meant to convey that either might be used.

The PRESIDENT said he would draw attention to one point, with respect to placing the engine on the surface for pumping instead of adopting the ordinary method. The useful effect got out of the Moore engine appeared to be only 68 per cent., but with ordinary pumping-engines the efficiency was at least 80 per cent. If they were to substitute a pumping-engine with 68 for one yielding 80 per cent., although probably the first cost (according to the figures given in the paper) might be less, yet the annual cost of fuel would be larger—probably nearly 20 per cent. more in the case of the hydraulic engine than with the ordinary pumping-engine. There was no doubt, in certain cases underground, the use of the Moore pumping-plant would prove very advantageous, and it seemed to be extremely ingenious; but he would very much hesitate to adopt it on the surface in preference to ordinary methods, on account of its low useful effect.

Mr. H. LAWRENCE referred to some experiments he made many years ago with a beam pumping-engine, which yielded 83 per cent. of useful effect.

Mr. R. T. MOORE agreed with the President that the direct-acting engine placed over the pit would give an efficiency of 80 per cent.; he had himself indicated as high as 85 per cent.; but it must be remembered that the direct-acting engine, pulling directly on the rods and lifting the plunger, was very different from the case in which the Moore hydraulic pump obtained 68 per cent., the pump being placed 800 yards down a mine with varying inclinations. Had the engine been fixed on the surface with the pump at the bottom of the shaft, the useful effect would no doubt have been much higher. He was prepared to agree with the President that a higher useful effect would be got by placing the steam cylinder directly over the pit and pulling directly on the plunger than with any arrangement such as that described in the paper or with electricity, but arrangements such as he had described had many advantages to commend them. There was the advantage of being able to place the steam engine at a distance from the pit and leaving the ground clear, and there were no moving parts in the shaft. Mr. Blackett had mentioned the questions of breakdowns with pump-rods, but he thought that with this system there would be no breakdowns in the shaft. The only moving parts were at the engine on the surface and at the pump underground; if the power-pipes were put in of sufficient strength, as there was no difficulty in doing, the repairs cost practically nothing. The loss by the friction of the water in the pipes was a very small matter. It was represented by a column of water 2½ per cent. of

the length of the pipes. With 4,000 feet of pipes, this was 100 feet of water or 43 lbs. per square inch, and this with an effective pressure of 1,000 lbs. per square inch was under 4½ per cent. As a matter of fact, in experiments which he had made there was not a great loss by friction in the pipes. It certainly represented much less fuel than the loss by condensation in a long range of steam pipes. One gentleman said that it was necessary to take only one pipe down the shaft in the case of steam pumps, but it must be borne in mind that in such cases they were using a fluid (steam) at 80 lbs. per square inch, whereas in the hydraulic pump they were working with 1,000 lbs., consequently a smaller pipe was needed at the higher pressure, and although two pipes were required the room taken by the two was not so great as by the one for steam. He thought that a steam engine underground was never so well looked after as one on the surface, and the tendency nowadays was to keep steam out of the pits as much as possible. With regard to duplicating pumps, those he referred to in the paper were simply two separate sets of pumps with two separate sets of power-pipes. Either set could be worked by disconnecting the pipes at the surface. They were really two entirely separate and distinct pumps.

Mr. H. LAWRENCE asked whether, supposing they were working at 40 or 50 fathoms and one of the pipes burst, they could work one-half of the pump while repairing the pipe?

Mr. R. T. MOORE—With this plant they could. When a valve was being changed in one of the pumps, one set of power rams on the surface was disconnected and the other kept going. As a matter of fact they had very little trouble with burst pipes; they were tested to two tons per square inch before being used.

Mr. C. C. LEACH asked if there was any trouble with the water in the case of frost?

Mr. R. T. MOORE said the joints were the ordinary hydraulic pipe coupling, tapering to the centre. They had had no trouble with the joints, and frost did not affect the water in the power-pipes while the pump was going. Pipes in exposed situations were covered with non-conducting material to prevent freezing when the pump was standing.

Mr. F. BERKLEY asked if either the sinking or the horizontal pump required much fixing?

Mr. R. T. MOORE said they did not.

Mr. MULHOLLAND asked if the length of stroke was the same in the pit as at the engine? It seemed to him that there would be some efficiency lost in the adjusting arrangements below.

Mr. R. T. MOORE replied that, so far as the adjustment by the valves was concerned, this only took place occasionally and only when there was some leakage. This might be not more than one stroke out of 100. There no doubt was loss on the particular stroke when it did touch the valves, but it was inconsiderable. With regard to the difference between the stroke on the surface and underground, although water was practically incompressible, it was not altogether so, and with this system, if there was a long length of pipes, the compression was such as to make the stroke underground rather shorter than on the surface; but this difficulty was overcome by making the plunger on the surface a little larger than the other.

Mr. W. C. BLACKETT said that this pump appeared for many in-bye purposes to be an extremely good one and probably one of the best, but he did not see that its use offered any advantage when placed at the pit bottom or in sinking pits. The writer claimed certain advantages by not having any moving machinery in the shaft, but there was the moving columns of water, and he did not see that this system possessed any advantages over steam. It appeared to him, too, that by putting steam down the shaft they would get a higher useful effect than either 68 or 70 per cent. The arrangement was fairly on all fours with compressed air, except that it gave a much higher efficiency. The writer mentioned that steam engines were not so well looked after underground as on the surface, but he (Mr. Blackett) took exception to this statement. He believed that in many cases they were quite as well looked after, but supposing they were not, that fact hardly constituted an advantage in favour of another system, inasmuch as the hydraulic motor which Mr. Moore would put down the pit was also an engine. However, the arrangement was an excellent one for certain positions in-bye, and if he was now in order he would move a vote of thanks to the author for his excellent paper.

Mr. R. T. MOORE said this was not an underground engine. It was no more complicated than an ordinary ram-pump, and did not require any more attention. He would like to draw attention to the fact that rods, even in a vertical shaft, did not give much better results than those he had got with a long length of pipes and varying inclinations; had rods been used in that case they would not have given nearly such a good effect. One advantage—he did not know whether he had made it quite clear—was that they could put the most economical form of rotary engine to drive the pumps, and he was inclined to think that, with high-speed triple-expansion engines, as good economical results could be obtained

with this system as by any direct-acting system. Steam pumps with the engine at one side and the ram at the other were wasteful of steam, and with a carefully constructed rotary engine on the surface one would get better results with this system than with a steam pump down the pit. There was always loss by condensation in taking the steam down the pit, and he was satisfied that the coal burned for raising a given quantity of water was much greater than with the hydraulic system at the Shotts Iron Co.'s Mauricewood mines, when hydraulic pumps were put in to replace steam pumps driven by steam taken down the pit and dip mines. The manager of the colliery stated that the monthly consumption of coal was reduced from 859 to 567 tons.

The PRESIDENT said it would be very interesting to know the useful effect of the engine at Balquhatstone colliery if it could be ascertained.

Mr. MOORE said he would obtain this information.

The PRESIDENT believed it would be the pleasure of the meeting to carry the vote of thanks proposed by Mr. Blackett. He was sure the paper had given them something to consider very seriously, and no doubt there was a great deal more in the invention than they already appreciated.

The motion was cordially adopted, and Mr. R. T. MOORE briefly acknowledged the compliment.

The SECRETARY read the following paper by Mr. Bennett H. Brough on the "Use of Cement in Shaft-sinking":—

USE OF CEMENT IN SHAFT-SINKING.

By BENNETT H. BROUGH.

Of late years there has been noticeable a distinct increase in the boldness of the application of Portland cement to engineering works. The advantages of substituting this material for cast-iron and timber are obvious. It neither corrodes nor decays; in damp situations its strength increases with age; and it is not appreciably subject to contraction and expansion.

In shaft-sinking cement is found a valuable auxiliary, and in the special setting of masonry, known as coffering, it is largely used for laying the rings of brickwork. Cement, too, has recently been employed in an ingenious manner on the Continent for consolidating shifting sand in water-bearing strata. The method employed consists in injecting powdered cement, by means of compressed air, steam, or water under pressure, into the ground to be consolidated. The cement is screened in order to free it from lumps, and the powder is taken by an injector which forces it through a flexible pipe into a perforated tube sunk in the soil to the required depth. In this manner the soil becomes impregnated with the powdered cement, whilst the water is driven away before it.

A more recent Continental development of the application of cement is the use of tubbing of cement-blocks for stopping back water where the strata contain large quantities. This process has been found to offer great advantages in cases where the pressure is excessive. The cement-blocks used are so shaped that they can be made perfectly water-tight. Their form, too, admits of easy setting. The shape of the blocks will be apparent from Figs. 1, 2, and 3, Plate XIX. They are segmental, and are provided on the lower side with a semi-circular groove, which corresponds with a semi-circular ridge on the upper side, the groove being slightly deeper than the corresponding ridge, so that space is available for the reception of cement-mortar. On each side of the block there is a hollowed-out channel for the reception of concrete, the weight of the block being in this way somewhat reduced. In each block two holes are cored out, one of which is central and vertical, whilst the other passes radially from front to back, not in the middle of the block, but at some distance below that point, and intersects the vertical hole. The height of a block is 30 to 40 inches, and its weight 1,543 to 1,763 pounds.

In tubbing a shaft with cement-blocks, the first layer of segments will be laid on the curb, and on this a second layer, and so on, the vertical joints being broken in each course. In order to place a segment in position, in the vertical hole a rod is placed which is provided with a ring or handle at the top and with a slot near the lower end. (Fig. 4, Plate XIX.) This rod is pushed down until the slot is opposite the horizontal hole, and then a bar (Fig. 5, Plate XIX.) is pushed through, until it passes through the slot and holds the rod fast in the block. The winding-rope may then be connected with the ring of the rod, and the block lowered into position. Previously, however, the trough in the block below is filled with cement-mortar. The ridge of the block when lowered coming in contact with the mortar forces it into every crack, and a water-tight connexion is effected between the horizontal layers of blocks. The vertical hole is then filled with a lump of clay which is rammed in, and a bar is pushed through the horizontal hole which has become choked at the point of intersection, and thus the whole is rendered free again. The rod is allowed to stay until the clay has hardened. On withdrawing it a channel is formed, through which the water collecting behind the tubbing can flow. Between every two blocks a tubular joint is formed, which is filled with cement-mortar or concrete rammed in as tightly as possible. The horizontal holes, which had hitherto served as drainage-channels, are closed by cork, wood, or clay. And if at a certain height in the shaft there is a supply of good water it may without difficulty be piped away.

This method has been successfully applied at the Cecilia ventilating shaft of the Serlo colliery, belonging to the Prussian Government, at Saarbrücken. The cement segments in this case measured 15·75 inches in thickness and 23·62 inches in height and in length. The shaft is 9 feet 10 inches in internal diameter. The bed having been formed and the wedging-curb placed in position, the laying of the cement segments was at once proceeded with. When the segments were formed into a complete ring, the perpendicular grooves were filled in with a special mixture of cement, and concrete was rammed in the space between the segments and the sides of the shaft. Above each cement block a thin layer of cement was spread, and on this the segments of the ring above were placed (Figs. 6 and 7, Plate XIX.).

In other cases a double ring of cement segments has been employed (Figs. 8 and 9, Plate XIX.). Here a course of cement blocks for the back wall is first laid, and concrete rammed in behind. This course is about half a block higher than the inner layer, so as to break the horizontal joints. The courses of the inner ring are then laid in such a

way that the vertical joints do not coincide with those of the back ring. The joints are carefully filled with cement, and the intermediate space, of about 4 inches, between the inner and outer rings is then filled with concrete tightly rammed in. In this manner a thoroughly water-tight tubbing is obtained.

The tubbing of a shaft 500 yards in depth and 17 feet 2½ inches in diameter, at the celebrated potash-salt mines of Leopoldshall, near Stassfurt, in Prussian Saxony, was constructed in this manner, in order to prevent the admission of the enormous volumes of water met with in the saliferous strata. Several shafts, too, in the Saar coal-field have been made on this system. The process has been patented in this country. (British patent, 1891, No. 12,145.)

The cost of putting in cement tubbing appears to be considerably less than that of the ordinary brick or iron tubbing. The cost of cement tubbing with a single ring of segments is 25s. 6d. per cubic yard. This estimate includes the cost of material and labour for making the blocks as well as the setting and filling with concrete. Thus, a ring of 13 feet 1½ inches in internal diameter and 13·78 inches in thickness, containing 183·65 cubic feet costs £7 7s. per yard. In the Bildstock shaft at Saarbrücken, which when complete will be 500 yards in depth, 197 feet of cement tubbing of these dimensions has been put in at a contract price of £12 17s. per yard.

In order to compare the cost of cement tubbing with that of brick and iron, the case may be cited of the cost of tubbing a shaft 17 feet 2½ inches in diameter, where large quantities of water had to be dealt with. At the prices current in Germany the cost of this would be as follows:—

	Per Yard.
1. Iron	£78
2. Brick	54
3. Cement	24

In the last case the tubbing consisted of a double ring of cement blocks, 13·78 inches and 9·84 inches thick respectively, with the 7·08 inches of intermediate isolating space, and the space behind the tubbing filled in with concrete. The estimate includes the royalty of 27s. per yard paid to the German company owning the patents. Cement tubbing of these dimensions was put in at the mines of Leopoldshall at a contract price of £21 4s. exclusive of royalty.

The process has not been in use long enough for any data to be available as to the durability of cement tubbing. So far, however, the tubbing put in has stood wonderfully well. The process is one full of

promise, and its development should be watched with interest. A great point in its favour is the simplicity of the design of the moulded cement blocks which should enable them to be made, without special machinery, on the spot where they are required to be used.

Mr. STEAVENSON observed that the block system had been patented, although so long as twenty-five years ago shafts had been lined with them. If there was a fissure in the side of the shaft and plenty of water flowing out of it, he did not think it would be possible to get liquid cement to set in the shaft. The particular process by which this was done might be patented, but the mere fact of using cement in the shaft was not new.

The PRESIDENT said that in 1861 Mr. Watson communicated a paper* on the subject of cement walling, in which a similar block system was explained, and in which an estimate of the cost was given showing the difference as compared with iron, brick, and cement, but he did not think they could go into this matter unless they had more detail as to the respective costs of material and labour.

Mr. W. C. BLACKETT asked for further particulars of the cost of £54 attributed to brick as compared with £24 for cement under similar circumstances?

Mr. M. WALTON BROWN said probably the most interesting of the systems referred to in Mr. Brough's paper was that briefly dealt with in the second paragraph, the use of injections of cement for consolidating quicksand or water-bearing strata. In the case of cement blocks, the writer did not refer to the increased cost of sinking the shaft at Leopoldshall with a rock diameter of at least 23 feet, so as to leave after insertion of the cement blocks, etc., a finished shaft with an internal diameter of 17 feet.

Mr. F. BERKLEY said one advantage of cement tubbing appeared to be overlooked, and that was it would not corrode like iron.

Mr. M. WALTON BROWN said the late Mr. J. J. Atkinson had calculated the relative thickness of cement tubbing required as compared with cast-iron, and proved that in no case could cement resist a head of more than 75 fathoms of water.†

Mr. R. T. MOORE said that the subway tunnels at Glasgow and of the Loch Katrine waterworks were lined with concrete without any brickwork, centres being used in the usual way and the concrete rammed in. The system, he thought, would prove equally efficient for lining shafts.

* *Trans. N. E. Inst. Min. Eng.*, vol. ix., page 73. † *Ibid.*, vol. ix., page 175.

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To illustrate Mr. Bennett H. Brough's "Note on the use of Cement in Shaft Sinking."

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Fig. 1.

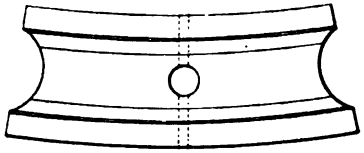


Fig. 2.

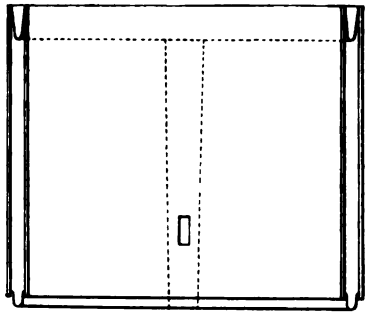


Fig. 3.

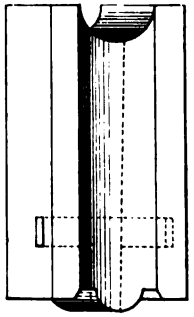


Fig. 5.

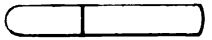


Fig. 6.

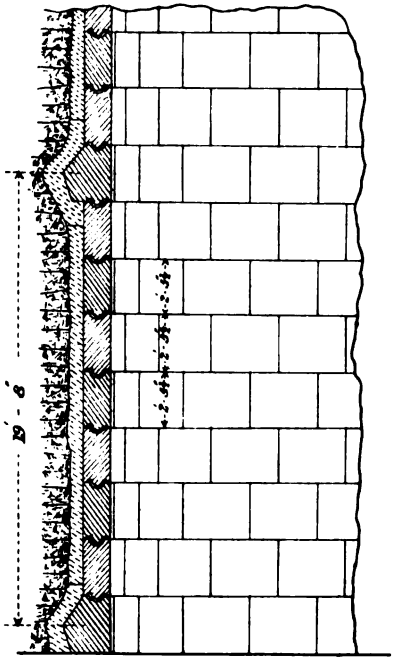


Fig. 7.

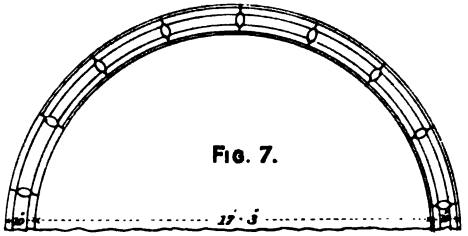


Fig. 8.

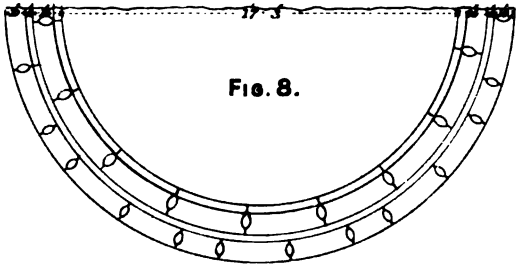


Fig. 4.

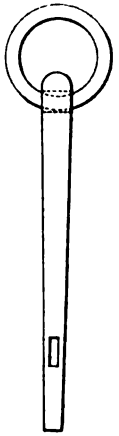
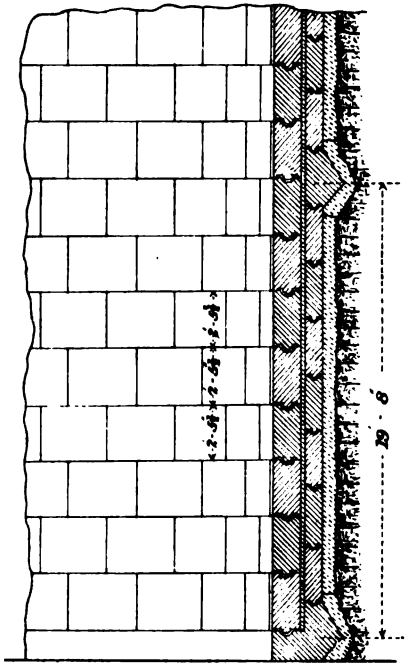


Fig. 9.



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Prof. ARNOLD LUPTON wrote, asking what were the depths of the top and bottom of the tubbing below the surface, what was the depth below the water-level, and how was the cement lining joined to the strata at the top and bottom and at the Cecilia mine, and at the Leopoldshall mine, and what was the thickness of the cement wall at the former mine? Referring to the costs of iron, brick, and cement tubbing, as given in the paper, perhaps Mr. Brough will explain why the cement tubbing was cheaper than brickwork, the cost of cement being, say, £2 per ton, and of bricks of first-class quality, say, 10s. per ton? Was the cement mixed with sand or with gravel to make concrete blocks, and if the latter, are the blocks of the same composition all through, or was there a facing of cement?

Mr. BENNETT H. BROUGH, in reply to the discussion, wrote that he regarded the President's reference to Mr. Watson's paper read in 1861, a paper that had escaped his notice, as a further proof that there was nothing new under the sun. Ample illustrations of the re-invention of forgotten appliances and methods were met with in mining practice. For example, the mine ventilator, called by the Cornish miners the duck machine, and by the Germans the Hartz air-pump, received a premium as a new invention from the Society of Arts, though there was very little reason to doubt that it had been in use for upwards of a hundred years on the Continent. Again, an ingenious co-ordinate protractor for plotting mine surveys was patented in the United States in 1886, although the identical instrument was described and figured two hundered years previously in a German treatise on mine surveying. Numerous other examples might be cited. In the case of the cement blocks, however, the German inventors could lay claim to originality in the shape, which facilitated the setting of the blocks. Mr. Watson's blocks appeared to have been of small size and shaped like ordinary bricks. The objections to the use of cement brought forward during the discussion appeared to be serious ones. It was possible, however, that means might be devised to enable the cement to withstand a greater head of water by enclosing a framework of iron in the block, a method that was largely adopted for fireproof floors. The cost of cement would be less than that of brick tubbing on account of the large size of the blocks, and the facility with which they were placed in position. He would obtain the information asked for by Prof. Lupton, and would, he trusted, be able to lay it before the meeting at the adjourned discussion.

DISCUSSION UPON MR. WILLIAM BOBY'S PAPER ON "THE MELDRUM SELF-CONTAINED DUST-FUEL FURNACE;"* AND MR. BRYAN DONKIN, JUN.'S PAPER ON "STEAM BOILERS WITH FORCED BLAST: THE PERRET SYSTEM FOR BURNING DUST AND REJECTED FUELS; WITH NOTES ON TESTING BOILERS."†

Mr. T. COLQUHOUN said the system described by Mr. Donkin—the Perret system—had been adopted at the West Stanley collieries some two years ago with the primary object of using up waste fuel, and it had been very successful. In the first instance, they used coal-mud and coke-breeze, the coal-mud being the refuse of the coal-washing apparatus; it was allowed to settle, and the water having been run off it was collected and used in about equal proportion with coke-breeze. They found it to answer very well, and it led them ultimately to try other kinds of waste fuel. They found that an inferior bottom coal would burn very efficiently. The system acted so satisfactorily with one boiler that they ultimately adopted the system for four boilers. During the early months of last year they burnt the bottom coal alone of the Shield Row seam for raising steam. They had used the duff of the upper seams, which was practically unsaleable, and it answered very well. When they had only one boiler on the Perret system, the remainder of boilers being ordinary Lancashire without forced draught, they had tried these different kinds of fuel with the ordinary Lancashire boiler, but failed to get steam for the current requirements of the pit, and they were compelled to burn a fuel which could otherwise have been sold or utilized for making coke. His experiments as regarded evaporative results had been very limited, and he would like to have them completed before placing them before the Institute.

The PRESIDENT hoped the results of the experiments would be communicated to the Institute at a later date.

Mr. COLQUHOUN said he would be most happy to submit them to the members.

Mr. A. L. STEAVENSON asked Mr. Colquhoun if it would not have been better to have utilized the coke-oven heat for raising steam?

Mr. T. COLQUHOUN replied that the waste heat of thirty-two coke-ovens was applied to two boilers for raising steam.

Mr. A. L. STEAVENSON said he noticed that Mr. Donkin, in his

* *Trans. Fed. Inst.*, vol. iii., page 250. † *Ibid.*, vol. iv., page 154.

paper, took as his unit the quantity of coal required to evaporate 1,000 gallons of water. He thought it would be better to stick to the quantity of water evaporated per lb. of coal, with which they were all familiar. Apart from mechanical questions, of which he had not had any experience, he thought the systems described appeared very satisfactory.

Mr. W. O. Wood said five Perret furnaces were working at Murton colliery. He had not tried any experiments to ascertain the evaporative power of the furnace, but its value consisted in burning refuse from the coal-washer which formerly went over the waste heap, with about as good results as obtained from good fuel consumed in the ordinary way. They got roughly the same amount of power from five boilers fired with refuse as from five fired under ordinary conditions with peas and duff. Possibily in the Meldrum arrangement, in which a steam blower was used, the expenditure of steam might not be greater than it would be in the case of a fan applied to the Perret furnace. It was a similar arrangement, and the results would no doubt be about the same, but he had not tried it, and it was only a question of whether steam was more economically used in the engine (driving the fan) or in the blower.

Mr. M. Walton Brown stated that with these furnaces it would be possible to burn household ashes and refuse, whose disposal was frequently a source of cost at collieries. Mr. Donkin stated in his paper that 2½ lbs. of water could be evaporated per lb. of house refuse, and it would probably be found that this efficiency would be exceeded, were ashes from workmen's houses, supplied with free coal, utilized for the purpose of raising steam.

Mr. T. Colquhoun said the waste fuel used was rubbish, which would otherwise have been tipped over the heap; such rubbish raised steam, when burned with forced draught, in such quantities that they had not had to add to their boiler power.

The President said he had been told by a gentleman who had given some attention to the subject, that they could get 50 per cent. more work out of a boiler under ordinary conditions than with forced draught.

Mr. T. Colquhoun said he had found the results were about the same with waste fuel and forced draught, as with good fuel without draught.

Mr. R. Laverick referred to a colliery where the Meldrum furnace was in use, and with factory small coal (peas and duff mixed) they got 17 per cent. more steam than with the ordinary furnace using the same class of coal, the total saving was estimated at 30 per cent.; this was effected by using an inferior class of coal, with less labour in stoking, and with less wear-and-tear owing to the furnace bars being kept cool, which

prevented clinkers setting upon them. There was more perfect combustion, the quantity of ashes being less than one-half what was produced in the ordinary furnace with natural draught.

Mr. C. C. LEACH said they would get more effect from the boiler but less from the coal.

Mr. R. T. MOORE said that in an instance in which they had adopted forced draught they simply took a 12 inches pipe to the boiler from a forcing fan which ventilated the colliery at about 1 inch gauge. They found less difficulty in keeping up steam; and it enabled them to use a very much thicker fire. With this inch of pressure the air was forced through the bars, the coal in the centre of the fire was wholly consumed and they got just as good results from inferior stuff as they had before from better stuff without forced draught.

Mr. M. WALTON BROWN said that Mr. Donkin gave a table of experiments which showed that the evaporation of water increased from 1,277 lbs. per hour without draught to 2,366 lbs. per hour with forced draught, but the efficiency was practically the same; without forced draught 9·9 lbs. of water were evaporated per lb. of fuel, whilst with forced draught it was 10 lbs., a difference of only 1 per cent.

Mr. B. DONKIN, Jun., wrote, in reply to the discussion, he was of opinion, as to the unit of comparison for steam boiler results, that the cost of fuel per 1,000 gallons of water evaporated, was decidedly the best. The pounds of water per pound of fuel should, however, always be added, as it gave the efficiency of a given fuel under a given boiler, but did not take into account the cost of evaporating 1,000 gallons of water for any given fuel, or the money paid to evaporate this quantity. This system was now generally used in the London districts to compare the efficiency of different boilers with different fuels. The boiler and apparatus that evaporated 1,000 gallons of water at the lowest cost of fuel was the most economical. Forced draught, now so largely used in boilers, could always be made to give greater evaporative results than with ordinary natural draught, and at lower costs. Combustion was more perfect, as shown by analysis of the waste gases. He might add that some fuels could hardly be burnt unless with forced draught.

The following paper was taken as read :—"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment—Part II." By Mr. A. G. Charleton.

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.*

By A. G. CHARLETON.

Part II.—The Relative Scope of Rival Methods of Ore Treatment.

Having examined the metallurgical nature of the various ores and processes (which have been superficially touched upon in the briefest possible manner), we are in a better position to proceed to the still more complicated and difficult questions of the relative prime cost of plant, working costs, and the percentage of gain or loss in rival methods of ore treatment. These are liable to differ in different countries, and under varying conditions even in the same neighbourhood, according to the nature of the ore, cost and quality of labour, material and supplies, as well as the economical or uneconomical manipulative or mechanical modifications in treatment, which can be introduced in each case, on which probably more than anything else, the individual economy or wastefulness (the profit and loss in fact) in works of the same class will depend.

To form an estimate of the prime cost of plant, we must either know the ordinary gross cost of a mill of a certain size and description in any particular locality, or, what is better, the actual quantities and prices of material of different kinds used, and the number of shifts worked by different classes of artizans at specific wages rates, in the construction of the foundations and superstructure of the building, and the erection of the machinery; as well as the price of the machinery itself, the weight of all the transportable material, and freight rates.

The collection of such facts is unfortunately too rare in mining operations to make it always an easy matter to form estimates of the kind applicable to different localities. It is only by piecing together fragments of information obtainable here and there that one can get anywhere near the truth.

Under the category of rival processes, the relative costs and results of treating the following classes of ore may be compared:—

1. Pyritic gold ores by chlorination in vats and chlorination in barrels, and by the new cyanide process, as well as by grinding (without roasting) in pans and arrastras.

* *Trans. Fed. Inst.*, vol. iv., page 233.

2. Silver ores in general,* by wet and dry crushing and pan-amalgamation, the patio and other processes, as compared with the ordinary and Russel lixiviation processes.
3. Free-gold ores by battery-amalgamation, both with and without grinding, and concentration.

The costs and loss in coarse-concentration and smelting have already been considered, and will not be referred to again.

There is no branch of ore treatment which admits of wider differences of internal detail than wet concentration (producing a corresponding effect on its cost†), but such points cannot possibly be entered into here; and as regards dry concentration, it cannot at present seriously be regarded as a rival to wet methods, and may therefore be passed over entirely.

The concentration of sulphide ores of gold and silver often depends on the relative proportion the sulphides bear to the gangue. No sharp line of distinction can be drawn between ores which are suitable for concentration or not, as average value and local cost of treatment enter into the calculation, but roughly speaking, such ores as contain 40 per cent. of sulphides are not usually suitable for concentration. Frequently an ore which will average 20 to 50 per cent. of sulphides, coming from the mine, is best divided by hand selection into first-class ore (to be treated by smelting, or some other process), and a second and poorer class for concentration.

In a mine where the ore runs in seams and pockets of solid mineral, it may happen that 100 tons of crude ore will contain on an average 20 per cent. of sulphides, which can be separated by hand selection into 20 tons of 75 per cent. sulphides and 80 tons of 6¼ per cent. sulphides. When this can be done cheaply it is often better than subjecting the whole 100 tons to the costs and losses of concentration, whilst it renders commercially possible a more expensive but more efficient process than the original ore could bear.

A point to be remembered, however, in concentration is, that clean, that is to say pure concentrates, are often as important to obtain as

* The term is applied to ores which do not contain more than, say 10 to 15 per cent. of lead. Ores with more than 15 per cent. of lead are known as silver-lead ores, and are smelted when circumstances admit of it, which is the only admissible proposition for their treatment. Carbonate of lead and galena are converted by roasting sometimes into oxy-chloride and sometimes into sulphate; the former goes into the amalgam, whilst the latter does not amalgamate, and this circumstance explains why some bullion of plumbiferous silver ores is free from lead, whilst other bullion sometimes contains 600 parts of lead in 1,000, according to the condition of the lead in the roasted ore.

† In western mining camps, the cost generally runs between 4s. 2d. and 12s. 6d.

clean tailings (which latter are essential for close saving). You may have the one without the other, and although a clean separation of the metallic components of the ore is almost always advisable, in some instances it may be desirable to leave a certain proportion of sand or gangue in the headings, either as a flux for smelting (as previously pointed out) or to lighten the pan-charges in amalgamation.

Vat and Barrel-chlorination.

For working a few tons of concentrates per day the regular Plattner process, with fixed tanks and long exposure to gas, is as convenient and economical as any of the improved processes, because the plant is simple and cheap to erect, and very few hands are required to run it.*

The production of gas is a simple question of relative costs of different chemicals delivered at the mine. For working large quantities of ore daily, especially if of comparatively low grade, which requires economy in crushing, roasting, gas consumption, labour, and time, the use of barrels, in place of fixed tanks, effects a saving in time and labour, and makes special watchful skill less important in the whole process than in the Plattner method, so that one of the modifications of the barrel system would be naturally adopted on crude ore and in dealing with large quantities of concentrates.

The attrition of the ore particles and the thorough turning over of the charge in the presence of nascent chlorine in the barrels, has also some effect upon the results, especially if there be coarse-gold present which has to be amalgamated afterwards, as the gold, it is said, is attacked with much greater avidity by the mercury in consequence of the clean surface created by the action of the chlorine and attrition combined. It is necessary, however, that the tailings should first be washed, by continuing the leaching, till all trace of chlorine has disappeared, and that they should be treated by amalgamation at once. If left to dry, the gold particles assume a red colour and amalgamate with great difficulty.

The most successful furnaces in general use for chlorination-roasting appear to be of three types:—

1. Plain or step-hearth reverberatories furnaces, of the Fortschaufelung class, with a hearth surface of about 12 feet wide by 75 feet long.
2. Horizontal round-hearthed mechanical furnaces, of the English Brunton-calciner type, about 12 feet in diameter.
3. A modified form of the Spence furnace.

* *Gold Amalgamation and Concentration*, page 28.

To which may perhaps be added an altogether new modification of the Fortschaufelung furnace, which will be alluded to later on.

When battery-amalgamation and concentration precedes chlorination, Mr. A. Thies* recommends the use of brass-wire screens in place of slot-punched sheet-iron ones, stating that when using 36-mesh brass-wire in place of 40-mesh slotted-iron, at Haile, in North Carolina, he obtained a far more uniform pulp for concentration, whilst the average life of the wire was found to be six weeks as compared with the sheets, which had to be thrown out in fourteen days, a matter which is worth noting. German practice certainly supports this view so far as concerns the effect of wire screens on the concentration results.

Dr. Egleston states that the correct amount of charge, in roasting gold-sulphides in the reverberatory furnace, is usually 10 to 12 lbs. per square foot of hearth ; an ordinary charge amounting to about a ton at a time on each division of the hearth, of which there are usually three.

A furnace of this description, designed to handle from 3 to 4½ tons of concentrates per 24 hours, 75 feet long by 11 feet wide inside, requires for its construction 40,000 common bricks, 8,000 firebricks, and 5 barrels of fireclay, and the ironwork, tie-bars, etc., exclusive of T-rails, weighs 11,000 lbs. A furnace with a 14 feet by 60 feet hearth requires 86,000 red bricks and 15,000 firebricks, and costs about £626 in Pueblo or Denver.

In vat-chlorination, the rest of the plant to correspond, covered in (as the furnace must also be), consists of a drier, a set of fixed or rotating leaching-vats, with (in some cases) silver-leaching tubs added, precipitating-tanks, and reagent tanks, well and pump, lead-generator, heating-pan and wash-bottle, a drying muffle and melting furnace, and a press and filters for precipitate, as well as filter-tubs for the base metals† in the waste-solutions, and cars for handling the ore, overhead tackle for lifting the vat-covers and tools, etc.

The cost of a plant of the kind in California, with a capacity of 6 tons in 24 hours, is stated‡ to vary between 6,000 and 7,000 dols. (£1,250 to £1,458 6s. 8d.). A small plant would cost about half the former sum.

The Thies modification§ of the Mears process (one of the most successful unpatented systems of barrel-treatment), requires the sub-

* "The Thies Process of Treating Low-grade Auriferous Sulphides."—*Trans. Am. Inst. Min. Eng.*, vol. xix., page 601.

† If present and worth the extra treatment.

‡ "The Milling of Gold Ores in California," by John Hays Hammond. *Eighth Annual Report of the California State Mineralogist*, page 696.

§ A description of this process is given by Dr. Egleston in *The Metallurgy of Gold and Mercury*, page 664, *et seq.*

stitution of rotating barrels for vats, the chlorine being generated inside the barrels, by the action of sulphuric acid (66 degs. B.) on bleaching powder, which is added to the charge of water and ore under ordinary circumstances in the proportion of 10 to 30 lbs. of chloride of lime to about 15 to 30 lbs. of acid per ton of charge of roasted ore in each barrel.

If copper is present more of these reagents are required.

The barrels must be run by steam or water-power, the latter being, of course, the most economical, when available.

The rest of the plant, though differently arranged, is substantially the same as that for vat-chlorination, and will cost not less than £620 for works with a capacity of 5 tons per day; the weight of the machinery will be about 17 tons.

The cost of the vat process at the works of the Plymouth Consolidated Company,* where 100 tons of concentrates is treated per month of thirty days (leaching taking twenty-four days), is given as follows :—

	£	s.	d.	£	s.	d.
Roasting—						
3 men at 10s. 5d. per day for 30 days	46	17	6			
1¾ cords of wood at 17s. 8½d.	46	9	8½			
54 lbs. of salt at 3s. 8d.	2	10	7½			
				95	17	10
Chlorine (employing two generators)—						
60 lbs. of manganese per day at £9 15s. 10d. per ton	7	1	0			
68 lbs. of salt „ 3 2s. 6d. „	2	11	0			
120 lbs of acid „ 12 10s. 0d. „	18	0	0			
				27	12	0
Leaching—						
40 lbs. of sulphuric acid for settling-tanks for 24 days	6	0	0			
40 lbs. of sulphuric acid for making sulphate of iron for 24 days	6	0	0			
Wages of leachers (2 men at £1 2s. 11d.†) for 30 days	34	7	6			
Wages of foreman	26	0	10			
				72	8	4
Total cost per month ...				£195	18	2

or £1 19s. 2d. per ton.‡

* *Trans. Am. Inst. Min. Eng.*, vol. xv., page 305.

† Two men on day shift attend to all the work of handling the ore after it is leached. The head man receives 12s. 6d., the others 10s. 5d. Only three tankfuls are leached every four days; but the men are employed steadily. The sulphate of iron is manufactured on the spot.

‡ To this should be added for assays, repairs, supplies, insurance, taxes, water, interest on invested capital, and deterioration of plant, as well as proportion of general expenses and superintendence, about 16s. 8d. additional per ton, making the total cost of working £2 15s. 10d. per ton.—*Eighth Annual Report of the California State Mineralogist*, page 48.

	Cost per Ton. (American Money.) Dollars.	Cost per Ton. (English Money.) £ s. d.	Gross Cost. Dollars.	Gross Cost. £ s. d.
Labour—				
Foremen...	·5600	...	3,006·43	...
Engineers and foremen	·0534	...	286·38	...
Gas generator	·2089	...	1,121·29	...
Salters	·0855	...	458·24	...
Floormen	·7604	...	4,080·83	...
Roasters	2·9400	...	15,782·49	...
Carmen	·2077	...	1,114·72	...
Carpenters	·0039	...	21·39	...
Labourers (white) ...	·0999	...	536·62	...
" (Indian) ...	·0309	...	166·00	...
Teamster	·0806	...	433·11	...
	$5·0312	£1 0 11½	$27,007·50	£5,626 11 3
Supplies—				
Acid	1·0220	...	5,486·38	...
Wood	1·5230	...	8,175·93	...
Coal	·0543	...	284·80	...
Furnace supplies ...	·0270	...	145·19	...
Manganese and salt ...	·8095	...	4,345·86	...
Pipe	·0089	...	47·90	...
Generator fittings ...	·0038	...	25·93	...
Leaching tanks... ...	·0638	...	339·05	...
Miscellaneous	·1353	...	727·26	...
Rake-heads	·0360	...	193·50	...
Car wheels	·0037	...	27·50	...
Repair account... ...	·1352	...	720·08	...
Electric light account...	·1077	...	578·49	...
Haulage account ...	·0549	...	294·77	...
	$3·9852	£0 16 7¼	$21,392·63	£4,456 15 11½
Total cost per ton of sulphides ...	$9·0164*	£1 17 6¾	$48,400·13	£10,083 7 2½
			Total gross cost.	

* In the six months ending November 31st, 1892, this charge was reduced to $8·42 = £1 15s. 1d. per ton of sulphides. As an instance of economical management, the total costs of mining and milling per crude ton extracted may be cited as follows, the ore being quarried in open benches :—

	Cents.		s.	d.
Mining	65	=	2	8½
Milling and concentrating	33	=	1	4½
Chlorination	19	=	0	9½
General expenses (mine)	8	=	0	4
General expenses (in San Francisco)...	2	=	0	1
Bullion freight, etc.	5	=	0	2½
Total cost ...	$1·32	=	5	6

per crude ton of ore, but the average for some time previous was 6s. 3d. per ton.

The roasting at these works is done in Spence automatic furnaces, each with four hearths, which roast 8 tons a day. On the hearth next the lower one, 3 per cent. of salt is added with a special spoon. The ore, instead of being as formerly stirred by fixed rakes, is now rabbled by oscillating ones, which tip every three minutes. On the upper drying-hearth they last a long time, but on the lower ones, where the heat must be great to drive off the last traces of sulphur, their life is only about three months.

Formerly the rakes stopped between the forward and backward motion just over the flue, now they are made to go beyond it, and are no longer exposed, as they were at this point, to the sulphurous gases and hot falling ore, which clogged the end of the shelves and gave such trouble at the Haile mine, finally causing the abandonment of the Spence furnace there for roasting fine ores, although admittedly a most excellent mechanical roaster for coarser grades of material in its original shape.

With the important modification above alluded to it seems doubtful (judged by the above facts) how far Mr. Thies' condemnation of the Spence furnace* (in works with a capacity of 3 to 4 tons) for fine ores (where a dead sweet roast is required) is entirely justified.

The labour involved in vat-chlorination on an average may be taken at :—

1 man, who works 10 hours, to bring in wood and ore.
1 man at the furnace, who works 8 hours.
1 chlorinator, „ 8 „
3 labourers (1 on shift by day, and 2 by night).

At Sutter Creek it takes 8 men for the whole 24 hours, one chlorinator, one helper, five men at the furnace, and one who wheels ore.

The consumption of chemicals per ton of ore is about as follows :—

Salt in the furnace	40 lbs.
„ „ generator	6 „
Manganese „	6 „
Sulphuric acid generator (66 degs. B.) ...	20 „

The stock of chemicals ordinarily kept on hand, on the scale of operations of the Alaska Treadwell Company, seems to be :—

	£ s. d.		£ s. d.
Salt, about 53 tons, valued at	2 17 11	...	153 9 7
Manganese, 13 „	9 15 10	...	127 5 10
Sulphuric acid, 35 tanks, at	8 18 10½	...	313 0 7½
Total value			£593 16 0½

* *Trans. Am. Inst. Min. Eng.*, vol. xix., page 610.

The works in Grass Valley, where vat-chlorination is most extensively used, guarantee an extraction of 90 per cent. of the gold, and 60 per cent. of the silver, but the saving more often amounts to between 90 and 94 per cent. of the gold in pyritic-concentrates, and over 60 per cent. of the silver, if the tailings are leached to obtain it.

The ore to be properly roasted ready for leaching should maintain a nearly vertical face when made into heaps on the finishing hearth, and cut down with a spadelle. It should show no bright specks, but be inclined to become black, which will generally be in 7 or 8 hours. The largest amount of gold has been shown to be in the best condition to be leached and to consume the least amount of chlorine in chlorinating it, when the ore falling in the furnace, in turning it over, has a slight violet colour. When the ore sparkles, and the sparks are numerous and bright, it shows that the roasting is not properly finished, and more salt has to be used.*

A ton of roasted ore will occupy usually 24½ cubic feet. This quantity is derived from 2,800 lbs. of raw sulphides, which occupy about 13⅔ cubic feet per ton (2,000 lbs.). A ton of sulphides will weigh from 1,450 to 1,700 lbs. after roasting, and occupy about 17½ cubic feet. The roasted ore ought not to contain more than 1⅝ per cent. of sulphur.†

At the Plymouth Consolidated works, the Fortschaufelungs-ofen used for roasting is 12 feet wide by 80 feet long, including the fire-box, the hearth being a continuous plane, but the charges, of which there are three in the furnace at one time, are kept entirely separate. They are called by the furnacemen the drying, burning, and cooking-compartments. In the middle division the ore is spread out very thin, and occupies about double the space of either of the others.

The furnace is worked by 8 hours' shifts, a charge being drawn and added in each shift. The charges weigh 2,400 lbs. and carry about 10 per cent. moisture.

The ore averages about 20 per cent. of sulphur, and just before the sulphur ceases flaming in the second division of the furnace 18 lbs. or ¾ per cent. of salt is added to the charge. Care must be taken to keep the concentrates damp until they are introduced into the furnace, or a decomposition of the pyrites begins, forming lumps which do not roast, and

* The heat on the finishing hearth must be maintained at a lively bright red, but not at a white heat, else the gold particles would melt, which, with a good magnifying glass, can be easily detected; after washing off the iron the gold appears then in minute globules, the chlorination of which is more difficult.

† Egleston, *Gold*, page 622.

consequently cause a loss of gold in the residues from leaching. The roasted ore from each shift is kept by itself on the cooling-floor until a tankful (about 4 tons) has accumulated from a single man's shift, and it is then worked by itself. This enables the foreman to better control the work of roasting, for if one lot out of three works badly, it points to the fault being with the furnaceman; whereas, if all three give unsatisfactory results, it may be presumed to be owing to a change in the ore, and the roasting must be modified.

The vats* for chloridizing the roasted ore are 9 feet in diameter by 3 feet in height; they are four in number, and are slightly inclined forwards to drain them completely. The bottom of each tank is composed of a filter about 6 inches thick, consisting of light strips of $\frac{3}{4}$ inch wood laid on the bottom at intervals of about a foot. Across these are placed 6 inch boards, spaced an inch apart. On this loose floor coarse lumps of quartz are spread, and on the top of this again quartz-sand, until a depth of 6 inches is obtained. Finally, this sand filter is covered over with another loose floor, the boards lying cross-wise to the loose floor beneath and pretty close together. This upper floor is merely to facilitate shovelling the charge out when it has been gassed to permit the removal of the leached ore without disturbing the filter.

The ore to be chloridized must be damp (about 6 per cent. moisture). The working test is to take a handful of ore and squeeze it, then open the hand, and if the lump immediately begins to crumble and fall apart (not run) the ore has the requisite amount of moisture. The damp ore is screened into the tank so as to lie as loose as possible and thus facilitate the penetration of the chlorine. A coarse screen of one-and-a-half mesh is used for this purpose.

The tanks are only filled up to within about 3 inches of the top, (to ensure the entire contents being covered with water in the subsequent leaching,) otherwise there would be great difficulty in washing out the soluble gold. As soon as they are full they are gassed. The gas is introduced into the bottom from two opposite sides, and is continued until ammonia held over the ore gives off dense fumes of ammonium chloride, which usually happens in about 4 hours. When this point is reached, covers are placed on the tanks and luted on.†

* The vats should be coated on the inside with asphaltum varnish or a mixture of pitch and tar applied hot, but the former is preferable, as it penetrates better into the pores of the wood.

† It is usual to provide the covers of the tanks with two pieces of $1\frac{1}{4}$ inches gas-pipe 6 inches long, and a square hole, 6 inches by 6 inches, closed with a wooden cover. These pipes are closed with balls of clay during the impregnation of the ore

The two gas-generators* which are employed to charge a tank are allowed to work on till nearly exhausted, when they are disconnected, and the holes in the tank are plugged up. The tanks are usually charged in the morning, and left standing two days. On the third day the ore is leached. The tank is first filled with water, and allowed to stand a few minutes to permit the water to penetrate the ore. If no more water is absorbed, the liquor is drawn off at the bottom, care being taken to keep the tank full of water during this part of the operation, which lasts 4 to 5 hours.

For charging the tank a gunny sack is laid on the ore and held down with a couple of bricks where the wash-water is afterwards to be introduced, in order to better distribute the water in the tank, and prevent it washing out holes and packing the ore.

The liquor from the leaching-vats is conducted to settling or storage-tanks, where about 40 lbs. of sulphuric acid is added (66 degrees B.) and it is allowed to stand 2 to 24 hours. It is then run into the precipitating-vats, where the gold is precipitated with sulphate of iron; the iron solution being added until after stirring, a further addition produces no purple colour. After the gold is precipitated it is allowed to stand from two to three days to settle, when the supernatant liquor is drawn off with syphons into a second settling-tank, where any gold drawn off by the syphons has a second opportunity of settling.

The liquor stands in this tank till it is necessary to run it off to make room for a fresh charge. Very little gold is found in this tank, so it is only cleaned out about once a year.

In the meantime fresh liquor has been run into the precipitating-tanks on the gold already precipitated there. In this way the gold is accumulated till the semi-monthly clean-up, the precipitating-tanks being kept locked and covered. In making a clean-up, the supernatant liquor is syphoned off, the gold gathered up, and placed in a filter of punched iron, lined with filter-paper, and washed with water till all the acid and iron salts are removed. It is then dried, melted in crucibles, and cast into bars.

Under unfavourable conditions the cost of the chlorination process may run up as high as £4 3s. 4d. per ton, but in California it may

with gas. After gassing, the clay is removed, and one of the pipes is coupled to the hose of the water-tank, whilst the other is connected either with another tank ready for chloridizing, or the ashpit of the roasting furnace, partly to utilize the surplus chlorine, as well as to protect the workmen from its injurious effects.

* When practicable, it is a good plan to heat the generators by steam in place of direct heat.

generally be taken as costing £1 17s. 6d. to £3 1s. 6d. per ton, £2 14s. 2d. being in all probability a fair average on a basis of treating 3 tons or more daily.

Mr. G. F. Deetken is responsible for the statement* that with favourable conditions of cheap wood and freight rates, not counting interest, insurance and amortization of a capital of 3,000 dollars, the working expenses in some parts of California do not exceed £1 0s. 10d., and are sometimes as low as 16s. 8d. per ton.

In locating works of this kind it is important to secure a good fall, and they should be terraced and so placed with reference to the prevailing winds that noxious fumes will not be carried in the direction of valuable land or house property.

There should also be a supply of water at hand, delivering 40 to 60 gallons per hour.

Barrel-chlorination.

Mr. Thies, in a letter to Mr. C. N. Aaron (a well-known Californian authority), gives the cost of the Thies process at the Haile mine, North California, as follows :—

Using a double reverberatory furnace, which furnishes 2 tons of roasted ore every 24 hours, with an average consumption of 1 cord of wood, at 5s. 2½d. per cord, and employing four labourers, the cost of roasting the ore amounts to 10s. 11¼d. per ton. Two men can easily treat 4 tons in 10 hours, elevate the ore, and clean out the filter-tanks, of which there are four to each barrel. Arranged on this basis, the cost of roasting and chlorinating amounts to 19s. 3¼d. per ton, as tabulated below :—

	Cost per Ton. s.	d.	s.	d.
Roasting 2 tons of ore—				
4 labourers at 4s. 2d.	8	4		
1 cord of wood at 5s. 2½d.	2	7¼		
			10	11¼
Chlorinating 4 tons of ore—				
2 labourers at 3s. 9d.	1	10½		
1 chlorinator at 8s. 4d....	2	1		
40 lbs. of bleaching powder at 1½d.	1	3		
60 lbs. sulphuric acid at 1d.	1	3		
Sulphuric acid, for making ferrous sulphate	0	6¼		
Repairs, wear and tear...	0	10		
Power	0	6¼		
			8	4
Total cost per ton			19	3¼

* *Eng. and Min. Jour.*, New York, vol. lv., page 244.

We thus have the sum of 19s. 3¼d. for roasting and chlorinating 1 ton of roasted ore, representing 1⅓ tons of raw iron pyrites.

Inside of 7 hours from the time the ore is in the chlorinator, the solutions are ready for precipitation and the tailings are clean.

At the Phœnix mine, in North Carolina, the cost for roasting* and chlorinating by the Thies process is estimated at :—†

	£	s.	d.
Roasting	0	9	1
Chlorinating	0	11	1
	£1	0	2

2,353 tons of concentrates are said to have been successfully treated by this process at the Haile mine and 5,000 tons at the Phœnix mine between May, 1888, and September, 1890.

At the Phœnix mine, a 12 feet revolving pan-furnace is used, which roasts 1 ton of raw ore in 12 hours, with a consumption of ⅜ths of a cord of wood, and 3s. 9d. worth of labour. The cost of power does not exceed 1s. 0½d. per ton.

At the Bunker Hill works, the concentrates are roasted with 1 per cent. of salt, in a reverberatory furnace 40 feet by 12 feet on the outside, with walls 18 inches thick, the stationary hearth of which (7 feet by 18 feet by 2 feet in height, with a working door on each side) terminates in a horizontal revolving hearth, 12 feet in diameter, set at a lower level (giving a fall of 6 or 7 feet). The discharge hole or cub is in the centre of this latter hearth, from which the ore drops into cars.

At the Deloro mine,‡ Canada, where the Mears process was formerly in operation, the ore was roasted (after drying in a revolving drier) in a pair of cylinders,§ one 30 feet in length by 5 feet in diameter, the other 20 feet by 4 feet, set tandem, jacketed with mineral wool and then paper. It is claimed that 10 tons of concentrates have been roasted in these cylinders in 24 hours, so that the extraction of gold has reached 93 to 98 per cent.

The tanks used in the process should be built of wood which has been soaked in linseed oil, dried, and painted with three good coats of white lead or tar.

* Removing the sulphur to within 0·25 per cent.

† Phillips, *Trans. Am. Inst. Min. Eng.*, vol. xvii., page 321.

‡ R. P. Rothwell, *Trans. Am. Inst. Min. Eng.*, vol. xi., page 191.

§ Different furnaces require, on the average, it is said, the following weights of wood to roast a ton of ore (the weights being calculated on the basis of 2,200 lbs. per cord as the average) :—White furnace, 300 lbs.; Bruckner, 900 lbs.; reverberatory, 600 lbs.; Stetefeldt, 200 lbs.—(Report, *Tenth Census, United States.*)

Mr. Thies states that the cost of barrel-treatment depends chiefly on the number of tons chlorinated per day.

The wear on the inner lead-linings of the chlorinators is imperceptible; a chlorinator in use at the Phœnix mine for over five years does not show any wear. The lining is fastened on with bolts from the outside, as it has been found very difficult to burn on lead, when chlorine has acted on it, in making repairs.

At the Haile mine, the fire-assay and value of the ore delivered to the stamps is 4·50 dollars (18s. 9d.) per ton.

The mint returns of bullion gave 16s. 3d. per ton of ore treated, of which 6s. 0½d. is to be credited to the battery, *i.e.*, to free-gold; whilst 10s. 2½d. was obtained from the sulphides.

Taking the assay-value of the ore at 18s 9d., and the actual yield in bullion at 16s. 3d., there is an indicated loss of 2s. 6d. per ton, or 13⅓ per cent. Taking the yield in free-gold at 6s. 0½d. per ton from an ore worth 18s. 9d. per ton (or approximately 32 per cent. of the gross value by assay), we have 68 per cent. to be debited to the concentrates. But the total yield in free-gold, and in gold from the sulphides being 16s. 3d., the ratio of the free-gold saved, to the total amount saved, is approximately 38 per cent., and the combined gold 62 per cent., or a saving of about one-third free and two-thirds combined gold.

The term, combined gold, has been used to express the condition of the gold which is not free. Whether the gold that is not free is chemically or mechanically diffused in the sulphides or both is uncertain, in most cases.

Mr. T. W. T. Atherton* claims to have found gold as a natural sulphide in the pyrites of the Deep Creek mines of New South Wales. He gives an analysis of the ore and the method pursued in experimenting on it, from which his conclusions were drawn.

From 80 tons of ore stamped per day of 24 hours at Haile, 7½ tons of concentrates are obtained from 16 Embrey end-shake tables, which gives as the yield of each concentrator a little less than half a ton.

The average assay-value of the raw concentrates for the 12 months preceding the date of Mr. Thies' paper was £6 5s. per ton, and the percentage of sulphur they contained varied between 40 and 45 per cent. In roasting, this was brought down to 0·25 to 0·40 per cent., whilst the value of the material naturally increased; the raw concentrates worth £6 5s. becoming worth when roasted £8 6s. 8d., or about one-third more per ton.

* *Eng. and Min. Jour.*, New York, vol. lii., page 698.

The assay-value of the tailings thrown away, after chlorinating the roasted ore, was, on the average, only 8s. 4d. per ton, representing an extraction of 95 per cent.

The process had been in successful operation 2½ years, at Haile, when Mr. Thies' paper was written in 1890, and 36,000 tons of crude ore had been treated profitably during that time, prior to which nearly every process had been tried on the ore and failed.

The advantages of the process are:—The small amount of space the plant occupies, speed of operation, high percentage of yield, facility of ascertaining the condition of the charge at any time,* and very slight wear and tear. The only offsets against these advantages are the care and intelligence required to control it, and the need for a small amount of power.

250 to 300 gallons of wash-water are needed per ton of ore treated (an ordinary charge), the water being introduced into the barrel first.

It takes 2 to 4 hours to chlorinate each charge, the barrel revolving at 12 revolutions per minute.

The lead-lining is ¼ inch thick, and weighs 12 lbs. per square foot.

The filters must be flooded from below with 4 or 5 inches of water to prevent the ore packing as it falls into them.

The charge must be allowed to drain, and then washed with water as rapidly as possible till the wash-water shows no gold, though still carrying traces of chlorine.

If lime is present, settling-tanks, called stock tanks, are required to settle the liquors which are drawn out of them into the precipitating tanks after standing for 14 to 16 hours.

The precipitating-tanks are large enough to hold the liquors from 3 tons of washed ore. The ferrous sulphate is syphoned into them. The solution must have a decidedly acid re-action in order to be certain that all the lime has been converted into sulphate.

The Providence works and those of Bunker's Hill may be cited, the former as showing exceptionally low cost by the vat process, working 9 tons per diem; the latter unusually high cost by barrel-treatment, treating 2 tons in 24 hours. To compensate for this the loss in the tailings, which used to run as high as £1 9s. 2d. when worked by the ordinary vat process, has been reduced 50 per cent.

* For this purpose a lead valve is arranged in the barrel, so that not only the pressure of an excess of chlorine gas but its actual presence can be ascertained at any time. It does not do to trust to the pressure test alone, other gases being some times given off.

	Ozs.	Dwts.	Gns.	Percentage Extracted.
[illegible]	2	7	21	96
[illegible]	1	3	22	97
[illegible]	6	9	23	97
[illegible]	1	2	6	97
[illegible]	0	16	5	95
[illegible]	12	10	10	95
[illegible]	3	16	0	94
[illegible]	1	10	11	93
[illegible]	0	7	8	85
[illegible]	0	8	17	96

[illegible] *Journal*, Nov. 5th, 1888.

It is stated that the cost of the plant for treating 100 tons a day is about £10,000.

It is certain that ores like those of Meadow Lake district, California, composed of a species of siliceous hæmatite (which in depth will probably be found in an unoxidized condition, consisting mainly of pyrite) will not amalgamate properly, and attempts have been made with various devices and countless processes to work them, but so far without success.

They are said to average £1 9s. 2d. to £2 1s. 8d. per ton or over, and to bear a resemblance to the ores of Bald Mountain district, South Dakota. It is possible that if a sufficient quantity of concentrates could be secured to keep works of the kind running many of these ores could be advantageously handled by the barrel-chlorination process, without a previous roasting, if treated with an oxidizing agent such as nitre cake, and in working the surface-ores even concentration might at first be dispensed with.

An interesting modification of the barrel process (described by John E. Rothwell, *Eleventh Census*, United States, 1890) is to make the chlorination-barrel also the washing and leaching-vessel. This is effected by fixing a diaphragm as a filtering medium, so as to form the chord of an arc of the interior of the barrel. The diaphragm or filter is made up of plates corrugated similarly to the ordinary filter-press plate, and perforated with holes every 4 or 6 inches square. These plates are supported on bearings bolted to the shell. On the top of the corrugated plates is placed the filtering medium—an open-woven asbestos cloth. It is about as coarse as the common gunny-sack, but the warp and woof are of much heavier thread.

Over this is placed an open grating, and the whole is held in place by cross-pieces, the ends of which rest under straps bolted to the inside shell. In this way, though the whole is rigidly held in place, it is very easily and quickly removed when necessary to change the asbestos cloth. Two valves on each end of the barrel above and below the filter, are provided for the inlet and outlet of the wash-water and solution respectively.

The barrel is charged by first filling the space under the filter with water, which at the same time is allowed to pass through the filtering medium and wash it, then the required quantity of water is put in above the filter. There are two methods of charging the pulp, lime-chloride, and sulphuric acid. In one the lime is so placed in the ore-charge in the hopper over the barrel that it goes in with the ore and is completely buried with it. The acid can then be added with very little danger of generating any gas before the plate on the charging-hole can

be put on and securely fastened. The other way, which seems still better, is to pour the acid first into the water, through which it sinks to the bottom in a mass, and does not mix. The ore is then let in, and the lime added last. The chances of generating any gas are stated in this way to be much less. A barrel so charged has been known to remain open 5 to 10 minutes after charging without generating gas, but it has been demonstrated that on the first revolution of the barrel the gas is at once liberated and creates considerable pressure. After the chlorination is complete the barrel is stopped, so that the filter assumes an horizontal position. The hose is attached to one of the outlet pipes, and conducts the solution to the reservoir tank. A hose is also attached to the inlet pipe, water is pumped in under pressure, and the leaching commences.

The air in the top part of the barrel is compressed, and forms an elastic cushion, which gives the wash-water perfect freedom to circulate over the whole surface of the charge, and wash every portion thoroughly with the smallest quantity of water possible. By washing in this way no gas is allowed to escape into the building. The solution runs into a covered reservoir-tank from which an exhaust fan draws the excess of gas, and discharges it outside the building. The length of time needed to do the leaching, varies with the leaching-quality of the ore. Charges have been leached in 40 minutes with a pressure of 30 to 40 lbs. per square inch. With higher pressures the time can be materially shortened. As can be readily seen, the ore in the barrel is in the best possible shape for rapid and perfect leaching. When the barrel is stopped, the ore settles on the filter, the coarsest and heaviest on the bottom, graduated evenly over the whole surface up through the charge to the slimes on top. In order to facilitate the leaching of charges carrying an excess of dust, a valve placed in the casing of the head (on a level with the surface of the pulp) is opened just after the barrel is stopped, and the slime remaining in suspension is run off into an outside washing filter-press, where it can be treated separately, and the charge washed in the usual way. The tailings are discharged into a car which will hold the whole charge of ore and water and then run out, or if water is abundant they are discharged into a sluice and washed away.

For leaching purposes the amount of water needed to wash a charge varies very little with the richness of the ore, going to show the perfect leaching-condition of the ore in the barrel. The amount required is about 120 gallons per ton more than the quantity used in the barrel for chlorination, which is about 100 gallons per ton.

In order to get a concentrated solution for after-treatment, and to

reduce the amount of solution to be treated, a tank is placed over the barrel, and when the richest of the solution and wash-water has run out into the reservoir-tank the discharge hose is connected with a pipe leading to the upper tank, and the washing is finished into it. The solution collected in this way is used in the next following charge in the barrel. The quantity of solution to be precipitated is thus reduced to 120 gallons per ton of ore treated.

The advantages claimed for this method are: (1) the freedom of the building from chlorine gas; (2) the control obtained over the perfect washing of the ore; (3) the small amount of labour, especially skilled labour, necessary; and (4) the small amount and simplicity of the machinery for the great amount of work accomplished.

One man of ordinary intelligence and a helper, are able to look after three barrels—charging, leaching, and discharging them. If the tailings are sluiced out no extra help is needed, but where they have to be trammed, one man in addition is necessary. The disadvantages are due to the necessary construction of the barrel, but do not interfere with its successful working. They are principally the amount of space taken up by the filter and the portion of the barrel underneath, and the fact that when the barrel is charged and running it is not perfectly balanced.

These disadvantages can be partly overcome by placing the filter close to the shell, only leaving sufficient space underneath to allow of free circulation, but bringing it up to the same height on the sides of the barrel as the horizontal filter; then, by using compressed air to displace the solution and wash-water, an equally good result can be obtained.

For the collection of the solution two tanks are necessary, each of ample capacity to hold a day's solution from all the barrels. Those for collection are placed on the same floor as the chlorinators (unless fall can be secured to place them below). On a step below are the precipitation-tanks, which should be of the same capacity and number as the collecting-tanks. The limit to size would probably be 50 tons capacity; where more is treated, another battery of tanks would be needed.

For a precipitant Mr. Rothwell recommends hydrogen sulphide gas generated from paraffin and sulphur or from iron sulphide and sulphuric acid as the cheapest and most satisfactory. It is generated, and then forced through the solution with a small air-pump, which at the same time forces air through, keeping the solution-tank in an agitated state and expelling any free chlorine gas. To save time the gas is turned into the tank while it is filling up, so that, when the tank is full, a few minutes finish the precipitation and collection. The tank is now allowed to stand two or

three hours, when it will have settled sufficiently to allow of the supernatant liquor being drawn off through a filter-press. There is little danger of precipitating arsenic and antimony which may be present when the process is worked cold, as they do not commence to come down till some time after the gold has been precipitated and collected.

This precipitant would not be, however, desirable with any considerable quantity of copper or lead in the solution, but small quantities can be dealt with in the after-treatment.

The loss in gold is considerably less if the precipitate is allowed to accumulate in the tanks, and a clean-up made after six or ten precipitations, than if it were filtered through a press and collected after every precipitation. There does not seem to be any advantage derived from a continuous precipitation and collection on this account if hydrogen sulphide gas is used, as the filters will soon become so coated and clogged with the sulphides as to retard rapid filtration without extreme pressure, which is sure to increase the loss.

The handling of a large number of filter-cloths is also a source of loss, no matter how carefully done. The asbestos filter-cloth under ordinary conditions will last 100 charges, and can be changed in about an hour and a half; one cloth has been known to last 150 charges.

The life of the supporting plates and grating can be made to equal the life of the lining of the barrel, and with barrels that have several thousand charges to their credit this shows little wear.

The latest suggested modification of the chlorination process appears to be that patented by W. D. Bohm, described and illustrated in the *New York Mining Journal* of December 31st, 1892. Briefly stated, the principles involved in it, are a forced upward circulation of the solvent solutions through the powdered ore placed in a suitable vat, of special construction.

The circulation is maintained until the precious metals are dissolved, when air-pressure is applied above the charge, to force out as much of the solution as possible, wash-water being subsequently forced up from below, or admitted above the charge, and then forced out in a similar manner, the previous constant flow upwards having caused (it is stated) such a deposition of the sand as to allow the liquid to be expressed rapidly and cleanly. It is claimed by using a solution of chlorine in water, and circulating it in closed pipes and vessels, that a considerable saving of gas is effected, and that as rapid results are obtained as with agitation, with much less power and wear and tear, while ores of different character can be treated in a short time and with little labour.

The plant is said to be equally applicable to cyanide treatment; the

precipitation of the gold being effected on shavings of an alloy of zinc and sodium is claimed to be more efficient than zinc alone. The chlorine water is circulated through the ore in a manner similar to a cyanide solution. It is claimed for the electrolytic chlorine-producing apparatus, the invention of two Russian chemists (which is worked in connexion with this process), that a great reduction in the cost of producing chlorine is effected; that common salt will supply the place of sulphuric acid and chloride of lime, that the machine is simple, requiring no skilled labour, and has been running with success at the El Dorado mine, Siberia.

This plant, in charge of an engine-driver, produces 40 lbs. of chlorine gas from less than 150 lbs. of common salt, utilizing 5 horse-power. The results are vouched for by M. Leon Perret, mining engineer to the Imperial Russian Government.

A diaphragm-pump of special construction prevents any emulsified grease or other undesirable matter from getting into the solution, and stops leakage of the gold solution through defective glands, etc.

The cost of working this process is stated to vary with the locality. Kaolin ores of Mount Morgan have been treated before the erection of the electrolytic chlorine generator at the following cost :—

	s.	d.
10 lbs. of bleach, at 4 cents	1	8
8 „ acid, at 2 cents	0	8
Labour and power	1	5½
	3	9½

The time occupied for each charge being 4 hours.

The extraction is not stated, but a proportionate increase in cost of chemicals would be necessitated in the treatment of ores requiring more chlorine.

Mr. Claude Vautin mentions, as recent useful innovations, glass-lined iron pipes, manufactured by Messrs. D. Rylands & Co.; enamelled iron diaphragm-pumps for conveying corrosive solutions, made by Messrs. Scott & Sons; and a compound containing upwards of 75 per cent. of available sulphuric acid, solid below the temperature of boiling water, which can be packed in iron drums, and shipped as ordinary cargo (obtainable from the Ore Dressing Co., 42, Old Broad Street); also chloride of lime packed in specially prepared iron drums. The form in which these two latter reagents are sold may be of utility to persons employing the chlorination process, especially in localities distant from a railway where transport has to be taken into account.

Mr. T. R. Rose,* commenting on Mr. Vautin's statement "that precipitated sulphide of copper is not to be recommended as a practical precipitant for gold, owing to its physical condition, and the facility with which it is oxidized to sulphate of copper," says:—"In accepting this statement as correct in a certain limited sense, it must not be forgotten that the suitability of the precipitant depends mainly on the manner in which it has been prepared. By adding a boiling saturated solution of sulphide (or rather a mixture of the polysulphides of sodium) to the equivalent proportion of a boiling saturated solution of sulphate of copper with vigorous stirring, sulphide of copper is precipitated in a granular form, which settles quickly in water. This substance is more active in the precipitation of gold than the fused sulphide. Its activity is due to the larger surface presented by the porous granules, and to the fact that it is easily decomposed. It is, as Mr. Vautin says, somewhat liable to atmospheric oxidation, but the loss, owing to this cause, is insignificant, because it is always kept covered with water, and can only take up such oxygen as may be dissolved in the latter. The granules of the sulphide of copper can be made the size of peas, under favourable conditions, and there is no practical difficulty met with in precipitating gold rapidly and completely by their use. A point in favour of the fused sulphide of copper is the readiness with which it can be obtained, and as it has been proved to answer well, there is no reason why it should be rejected in favour of the precipitated salt."

The Cyanide Process.

The plant required for the MacArthur-Forrest process consists of crushers (stamps or rolls) to pulverize the ore to 20 to 60 mesh, and leaching and precipitating-tanks of much the same description as those used for chlorination; but as its professed object is the treatment of the ore in bulk, the number of tanks, etc., required for this method of treatment are of necessity much larger than in chlorination works. The cost of erection of such a plant on a basis of treating 50 tons per day would not, so it is said, ordinarily exceed £6,250, everything included.

The report of Mr. J. R. Bradshaw (assayer, etc., of Charters Towers) states, without going into details, that from information he received at Ravenswood, North Queensland, it can be worked there to profit at a cost of £2 per ton, but the cost must of necessity depend on the district and surrounding circumstances.

Mr. Bradshaw claims, moreover, economy for the process in regard

* *Mining Journal*, March 11th, 1893, page 276.

to time occupied in treatment, as compared with raw amalgamation in pans, stating that with an ordinary wheeler, ½ ton of auriferous stone of about 2½ ounce grade is decomposed in 6 hours, representing the capacity of one wheeler as being equal to treating 12 tons per week. Mr. McIntyre, the company's manager at Ravenswood, he goes on to state, is erecting two wheeler pans, measuring 5 feet in diameter, capable of carrying a charge of 3 tons of ore each, and it will thus be seen that with two pans, 24 tons of ore can be decomposed in 24 hours.

It would be interesting to learn how those arithmetical calculations panned out in actual practice as regards power consumed and other details.

A test of the Ravenswood ore made by Mr. Bradshaw gave an extraction of 89 per cent. of the gold and 70 per cent. of the silver.

If the success of the process demanded the mechanical incorporation of the cyanide solution with the ore in pans, it would seem likely to be foredoomed to failure, and on this account the idea is now almost entirely abandoned.

It would probably be found that, for convenience and speed, barrels could be advantageously substituted for pans, but modern developments of the process have done away with the original notion of auxiliary agitation.

The Chemistry of the Cyanide Process.

This has been ably dealt with by Messrs. Charles Butters, Ph.D., and J. E. Clennel, B.Sc., in a series of papers which appeared in the *New York Mining Journal*, in October last, from which the following extracts are taken :—

Elsner has shown that the very finely divided gold obtained by precipitating a solution of the chloride with ferrous sulphate may be dissolved by potassium cyanide, provided there is an excess of oxygen present.

The compound formed may be looked upon as a double cyanide of gold and potassium (KCyAuCy), and the reaction which takes place may therefore probably be represented by the following equation :—

$$2Au + 4KCy + O + H_2O = 2KAuCy_2 + 2KHO.$$

Two interesting points are indicated by the above equation, which it is well to bear in mind, in applying potassium cyanide as a gold solvent on a commercial scale :—

1. That the quantity of cyanide theoretically capable of dissolving a given amount of gold is infinitesimal, compared with the weight actually required in practice. Taking Au = 196·8,

K = 39·04, and Cy = 25·98, it will be observed that 130·04 parts by weight of potassium cyanide, should be capable of dissolving 196·8 parts of gold, or approximately two parts of the cyanide salt should dissolve three parts of gold. The minimum actual consumption in treating free-milling ore, assaying, let us say, 10 dwts. per ton, is about 3 lbs. per ounce of gold recovered, or roughly forty parts by weight of cyanide for one part of gold. In the leaching-tanks alone 1 lb. of cyanide is generally consumed per ton of material treated.

2. That an extremely small quantity of surplus oxygen is sufficient to cause the solution of the gold, 15·96 parts being required for 393·6 parts of gold, or say as 1 : 25. The air present in a porous mass of tailings, with that dissolved in the water used in making up the solution, is in fact more than ample to effect the reaction. To explain the enormous excessive consumption of cyanide, we must bear in mind the great instability of the simple cyanides.

Hydrocyanic acid is liberated from its salts by all mineral acids, carbonic acid, and all common organic acids. Atmospheric carbonic acid is sufficient to set up a certain amount of decomposition, in which a constant evolution of hydrocyanic acid takes place as follows:—

$$2KCy + CO_2 + H_2O = 2HCy + K_2CO_3.$$

Then, again, we must consider the proneness to oxidation which the cyanates exhibit, and which in fact lies at the base of most of their technical applications. Potassium cyanide readily changes into cyanate and ultimately into carbonate:—

$$KCN + O = KCNO;$$

$$2KCNO + 3O = K_2CO_3 + CO_2 + N_2.$$

The presence of alkalies, which always occur in commercial cyanide, tends to induce the peculiar and little understood decomposition termed hydrolysis, which seems to be mostly produced in the zinc boxes by the presence of that metal.

In the reaction alluded to above, the alkali appears to determine a chemical change in which water plays a part, while the alkali itself is not in the least affected.

There are good grounds for supposing that in dilute solutions a dissociation of the cyanide takes place, so that what we term a weak solution of potassium cyanide is in reality a mixed solution of potassium hydrate and hydrocyanic acid:—

$$H_2O + KCy = HCy + KHO.$$

This being the case, it is only natural that hydrocyanic acid should be constantly given off from all vessels in which weak cyanide solutions are freely exposed to the air, and its smell is, in fact, generally noticeable in the neighbourhood of the tanks in which it is stored.

The consumption of the reagent is on these grounds evidently enhanced by the agitation or circulation systems, since these methods involve a constant exposure of fresh surfaces.

Another source of waste is due to the tendency of the simple cyanides to form double salts with each other, or with other metallic compounds.

Salts of iron, and to a lesser extent of aluminium, magnesium, calcium, and the alkali metals are liable to occur in the tailings, especially after long exposure to atmospheric influences.

It seems, therefore, that under the most favourable circumstances an enormous waste of cyanide must take place, which may partly, however, be mitigated by the use of closed tanks and careful attention to the purity both of the cyanide itself and the water employed to dissolve it.

Action of Cyanide on Pyritic Material.—Various additional decompositions take place, when cyanide is applied to the treatment of pyritic ores or tailings. The surface ores of the celebrated banket formation of South Africa consist almost exclusively of silica and oxide of iron, the silica occurring in the form of rounded pebbles, embedded in a softer matrix highly charged with ferric oxide, which gives it a characteristic reddish tinge. The gold* is found in this matrix associated with the oxide of iron, or sometimes in small scales on the surface of the pebbles. The pebbles themselves carry little or none.

At a lower level this free-milling banket passes into an ore precisely similar in structure, but much harder, and containing the iron in the form of sulphide instead of oxide, which gives it a peculiar bluish tint.

There can be no doubt that the free-milling ores have been formed by the gradual oxidation of the pyrites through the influence of air and moisture during a long period of time, and in fact we see this change in progress, wherever pyritic material has been exposed to the action of the atmosphere. The first effect observed is the conversion of ferric sulphide

* Taking into account the production from tailings and concentrates the average yield of the Witwatersrandt ore was 12 dwts. 5 grains per ton in 1891 and 12 dwts. 13 grains in 1892. At the end of 1891 there were 1,540 stamps in operation, which yielded 11·23 dwts. per ton by direct amalgamation, whilst the average of free-gold saved fell in 1892 to 9·87 dwts., 2,035 stamps being in operation at the close of the year; the total yield having increased rather than fallen off goes to show that though the ore with depth has become more sulphuretted, it has so far been successfully treated.

into a soluble sulphate, free sulphuric acid being liberated. By the action of the air again on the ferrous sulphate, certain insoluble basic sulphates of variable and somewhat complex composition are found to result, whilst a certain amount of soluble ferric sulphate is likely to be produced at the same time.

The pyritic ores of the Witwatersrandt contain also small amounts of copper, arsenic, and sometimes cobalt and nickel, but the amount of these foreign metals has hitherto been so small that it has not practically interfered with the process.

As the fact has been observed, however, at the Robinson chlorination works, that copper and arsenic seem to occur in gradually increasing quantities with the increasing depths of the mines from which these concentrates were purchased, it is possible that these elements may be a serious source of trouble in the future.

If one attempts to treat a charge of partially oxidized pyritic tailings directly with cyanide solution, the free sulphuric acid present which renders the moisture they contain distinctly acid, sets free hydrocyanic acid. Ferrous sulphate (green vitriol) reacts upon the cyanide with the formation of ferrous cyanide, a yellowish-red flocculent precipitate:—

$$FeSO_4 + 2KCy = FeCy_2 + K_2SO_4.$$

This, however, under ordinary circumstances is slowly converted into potassium ferrocyanide by the excess of cyanide present:—

$$FeCy_2 + 4KCy = K_4FeCy_6.$$

If sufficient acid be present, the ferrocyanide reacts on an additional quantity of the ferrous salt, ultimately giving rise to a blue precipitate or coloration (Prussian blue):—

$$3K_4FeCy_6 + 6FeSO_4 + 3O = Fe_2O_3 + 6K_2SO_4 + Fe_7Cy_{18}.$$

A coloration of that sort on the surface of the tailings or in the solution is therefore a sure indication that acid iron salts are present, and that a large waste of cyanide is taking place.

Ferric salts, when present unmixed with any ferrous compounds, decompose the cyanide solution with evolution of hydrocyanic acid, and precipitation of ferric hydrate:—

$$Fe_2(SO_4)_3 + 6KCy + 6H_2O = Fe_2(OH)_6 + 6HCy + 3K_2SO_4.$$

This reaction takes place in two stages, the first being the formation of a soluble but very unstable ferric cyanide, giving a dark brown solution:—

$$Fe_2(SO_4)_3 + 6KCy = Fe_2Cy_6 + 3K_2SO_4,$$

which decomposes as follows:—

$$Fe_2Cy_6 + 6H_2O = Fe_2(OH)_6 + 6HCy.$$

This gives rise to ferric hydrate, part of which, being in a finely divided

colloidal condition, is with difficulty removed, as it chokes the pores of the filters.

A mixture of ferrous and ferric sulphates, such as is probably always present in partially oxidized pyritic tailings, causes the appearance of a blue colour on the addition of cyanide, after the free alkali of the commercial product has been neutralized, Prussian blue (ferric-ferrocyanide), $Fe_4 (FeCy_6)_3$, being produced when the ferric salt is in excess, and Turnbull's blue (ferrous-ferricyanide), $Fe_3 (FeCy_6)_2$, when the ferrous salt predominates.

Before attempting to treat pyritic material or products with cyanide, it is necessary therefore to get rid of the free sulphuric acid and soluble iron compounds. This is generally done by leaching with water until the liquid running off the tanks no longer shows a coloration with ammonium sulphide. After this treatment the insoluble basic sulphates which still remain, and being gradually decomposed by water, would act upon the cyanide solution, are dealt with by washing with caustic soda or lime water. This converts the basic salts into ferric hydrate and sodium or calcium sulphates. When the quantity of free acid and iron salts is small, the preliminary wash-water may be advantageously omitted.

Lime in the dry state is sometimes mixed with the tailings before the cyanide treatment commences. When this method is adopted the iron is precipitated as a mixture of ferrous and ferric hydrates. After the washing with alkali is completed, the tanks are allowed to drain, and strong cyanide solution of about 6 per cent. is pumped on.

Even after this treatment the consumption of cyanide with moderately pyritic tailings, which have been partially decomposed by exposure, is found to be four times that which occurs with free-milling material.

The presence of a large excess of alkali in the solution brings about various secondary reactions, which lead to a loss of cyanide, such as the hydrolysis before referred to, and a peculiar action in the zinc box mentioned later.

Lime though slower in its action is preferable to caustic soda as a neutralizing agent, as it is equally effective in decomposing the iron salts, less active in producing secondary reactions on the cyanide, and also less energetic in attacking the zinc in the precipitating-boxes.

Ferric hydrate does not appear to be acted upon by potassium cyanide, but ferrous hydrate, which is formed on the neutralization of the iron salts by alkalies, reacts on the cyanide in excess, with the formation of ferrocyanide of potassium :—

$$Fe (OH)_2 + 6KCy = K_4FeCy_6 + 2KOH.$$

Deposition of Gold from Cyanide Solutions.—Under certain conditions, such as the absence of sufficient oxygen in the solution, a partial precipitation of the previously dissolved gold appears to occur. If by any chance the solution should become acid, there is a decomposition of the double cyanide of gold and potassium, in which the gold is generally supposed to be thrown down as (insoluble) aurous cyanide :—

$$KAuCy_2 + HCl = KCl + HCy + AuCy.$$

In working on the circulation-and-transfer system it is found that where pyritic material is under treatment it is not safe to transfer a solution already rich in gold to a fresh lot of tailings, as the extensive decomposition of the solution which takes place may lead to a final loss of gold.

Selective Action of Cyanide.—It is claimed by the inventors of the MacArthur-Forrest process, that in a mixture containing metallic gold, silver, copper, and base metals, cyanide of potassium exerts a selective action, dissolving first the gold, then the silver, and afterwards attacking the copper and baser metals.

The process, however, does not appear to have been successfully applied to ores, such as are met with in parts of California and Australia, containing considerable quantities of foreign metals.

Ores containing sulphides of silver and copper produce considerable decomposition of cyanide, the copper being partially dissolved as sub-sulpho-cyanide, the silver, however, remaining unattacked.

In two experiments carried out by Mr. Wm. Bettel, chief chemist of the Robinson Gold Mining Company, on an ore from the Albert silver mine (containing 30 ounces of silver per ton and 10 per cent. of copper), it was found that no extraction of silver occurred, this metal being present as sulphide.

Action of the Zinc Shavings on the Solution.—We must now consider the action of the zinc on the gold cyanide solution. Theoretically, a simple substitution of zinc for gold occurs in accordance with the following equation :—

$$2KAuCy_2 + Zn = K_2ZnCy_4 + 2Au.$$

Taking Zn = 65·1, Au = 196·8, it follows that 65·1 parts by weight of zinc should be sufficient to precipitate 393·6 parts of gold, or 1 lb. of zinc should precipitate 6 lbs. of gold. The actual consumption of zinc is about 1 lb. per troy ounce of gold recovered. It is evident, then, that zinc is consumed in some other way than in mere replacement of gold.

During the passage of the solution through the zinc boxes a constant vigorous evolution of small bubbles may be noticed, which are found to consist chiefly of hydrogen. The outflowing liquid is found to possess a

greater degree of alkalinity than it had on entering at the head of the box, and a smell of hydrocyanic acid and sometimes of ammonia is constantly observed in the neighbourhood of the boxes.

It is clear, then, that a decomposition of the potassium cyanide solution itself by the zinc is in progress, and this is not to be wondered at when we consider the powerful electro-chemical effect which must be produced by the contact of such a highly positive metal as zinc with a strongly negative metal such as gold.

Ordinary commercial zinc loses weight when immersed for some time in cyanide solution, but the action is slow. It is doubtful whether pure potassium cyanide would have any action at all on chemically pure zinc. It is well-known that the copper-zinc couple produced by immersing zinc in a solution of a copper salt decomposes water.

An analogous reaction of the zinc couple accounts for the evolution of hydrogen above-mentioned :—

$$Zn + 2H_2O = 2H + Zn\,(OH)_2.$$

The hydrate of zinc is at once dissolved in the excess of cyanide :—

$$Zn\,(OH)_2 + 4KCy = K_2ZnCy_4 + 2KOH,$$

which reaction accounts for the increased alkalinity of the solution.

There are reasons for believing that the black deposit formed on the zinc shavings is an actual chemical compound of gold and zinc, which acts as the negative element in the electric couple, the undecomposed zinc forming the positive element.

When strong solutions of caustic soda have been used for neutralizing the acid salts of the ore, a white deposit is frequently observed on the zinc. The alkali first attacks the metal to form a zinc-sodium oxide :—

$$Zn + 2NaHO = Zn\,(ONa)_2 + 2H.$$

This then reacts on the double cyanide of zinc and potassium always present in the solution, and precipitates the white insoluble simple cyanide of zinc :—

$$2H_2O + Zn\,(ONa)_2 + K_2ZnCy_4 = 2ZnCy_2 + 2NaOH + 2KOH.$$

This reaction is of some importance as affording one means by which the excessive accumulation of zinc in the solutions is avoided.

Affinity of Zinc for Cyanogen.—Potassium auro-cyanide ($KAuCy_2$) appears to be one of the most stable of the salts of gold, and the reaction in the zinc boxes, shows that the affinity of zinc, together with potassium, for cyanogen, is greater than that of gold with potassium for the same radicle. Hence a solution of potassium cyanide cannot dissolve gold which is in contact with zinc, neither can gold replace zinc in a solution of the double cyanide of zinc and potassium. So long as any zinc is present,

therefore, we need not fear that the precipitated gold will redissolve in the excess of potassium cyanide flowing through the boxes.

It is evident also that the cyanogen contained in the double cyanide of zinc and potassium is not available for dissolving gold, nor when a solution charged with zinc is employed in the treatment of a fresh lot of tailings it is only effective in so far as it contains a certain quantity of simple cyanide of potassium or other alkaline cyanide.

New Methods of Precipitation.—The cyanides of sodium and ammonium and those of the alkaline earths (calcium, barium, etc.) will dissolve gold as well as potassium cyanide. Sodium cyanide is more difficult to manufacture than the potassium compound, but a given weight of it should be more effective than the same weight of potassium cyanide, inasmuch as 49 parts of the former are equivalent to 65 of the latter.

The advantages of Molloy's process and others which employ sodium or potassium amalgam will be referred to later. The alkali metal is obtained by the electrolysis of the carbonate between electrodes of lead and mercury :—

$$Na_2CO_3 = Na_2 + CO_2 + O.$$

The sodium forms an amalgam with the mercury. Sodium amalgam may also be manufactured direct from its elements. It is claimed for this method of precipitation that the whole of the cyanogen is restored to a condition available for dissolving gold as shown by the reaction :—

$$Na + KAuCy_2 = Au + KCy + NaCy.$$

Composition of the Zinc Slimes.—Any base metals which happen to be in solution in the cyanide liquor are liable to be precipitated by the zinc along with the gold. Hence the zinc slimes are found to contain a certain percentage of copper as well as traces of arsenic and antimony. Moreover, any impurities in the zinc will also find their way into the slimes, as zinc will be dissolved by the cyanide in preference to any less oxidizable metals, *e.g.*, tin and lead. Silver is dissolved by the cyanide and re-precipitated by zinc by a set of reactions precisely analogous to those of gold :—

$$2Ag + 4KCy + O + H_2O = 2KAgCy_2 + 2KOH, \text{ and}$$
$$2KAgCy_2 + Zn = K_2ZnCy_4 + 2Ag.$$

It has been observed that the proportion of silver to gold is greater in the cyanide bullion than in the gold from the batteries, and this is explained by supposing that the loss of silver in amalgamation is greater than that of gold.

Treatment of the Zinc Slimes.—The removal of the zinc is a troublesome operation, and is only very partially carried out in smelting the

dried slimes. The admixture of sand is made for the purpose of forming a fusible silicate of zinc.

A portion of the zinc is volatilized and burns at the mouth of the crucible with a greenish flame, producing the white oxide (ZnO), which is found encrusting the flues, and no doubt carries with it no inconsiderable quantity of gold and silver. The most promising method of treating these slimes appears to be that suggested by Mr. Bettel of fluxing with acid sulphate of soda and fluorspar.

Attempts to remove the zinc prior to smelting have been only partially successful, as all such methods involve the filtration of a slimy mass, which retains soluble salts with great tenacity.

The slags from the fusion of the zinc slimes contain a considerable amount of gold, some of which is in the form of round shot, and may be removed by pounding up the slag, passing through a coarse sieve, and panning off. The residue from the first fusion should always be fused again with additional lead to form an alloy with the gold. The same lead bars may be used for a number of successive fusions of the slag, and when sufficiently enriched the gold can be recovered by cupellation.

Testing of Cyanide Solutions.—It is a matter of importance to determine exactly what strength of cyanide solution is used in treatment of tailings. The ordinary method of testing depends on the fact that silver cyanide is soluble in excess of potassium cyanide, with the formation of a double cyanide of silver and potassium :—

$$KCy + AgNO_3 = AgCy + KNO_3, \text{ and}$$
$$AgCy + KCy = KAgCy_2.$$

When silver nitrate solution is added drop by drop from a burette to a solution of cyanide a white precipitate is formed, which quickly redissolves. At a certain stage the precipitate becomes permanent, when, in fact, the whole of the cyanide has been converted into the soluble silver salt, and an additional drop of silver nitrate produces a permanent precipitate of the insoluble simple cyanide of silver :—

$$KAgCy_2 + AgNO_3 = KNO_3 + 2AgCy.$$

From these reactions 107·66 parts by weight of silver are equivalent to 130·04 parts of potassium cyanide. A convenient standard silver solution is one of such strength that every cubic centimetre added to 10 cubic centimetres of the solution to be tested, corresponds to 0·1 per cent. of pure potassium cyanide.

This method gives good results when pure cyanide solutions are under examination, but when the solutions contain zinc it is difficult if not impossible to determine the end of the reaction. A white flocculent pre-

cipitate occurs at a certain stage, probably consisting of simple (insoluble) cyanide of zinc, formed by the decomposition of the soluble double cyanide.

This precipitation occurs long before the whole amount of potassium cyanide has been converted into the soluble double salt of silver ($KAgCy_2$) for the solution after the appearance of the flocculent precipitate still gives the Prussian blue reaction with acidulated ferrous sulphate.

A standard solution of iodine in potassium iodide may be used with great accuracy for determining the total amount of cyanogen in a solution whether in combination with zinc or not, making use of the reaction :—

$$KCy + I_2 = KI + ICy.$$

The colour of the iodine is discharged so long as an excess of cyanide is present. The sharpness of the terminal reaction may be increased by adding a small quantity of starch to the solution under examination, which gives a permanent blue colour as soon as an excess of iodine has been added.

What is most needed, however, is a rapid method of determining the amount of cyanide available for dissolving gold, for, as was pointed out above, the cyanide in combination with zinc is not available for that purpose.

The method of testing solutions containing zinc for available cyanide which was introduced by Mr. Bettel at the Robinson Company's works is as follows :—Two perfectly clean flasks of equal size are taken. To each of these is added a considerable bulk, say 50 cubic centimetres of the solution to be tested and 50 cubic centimetres of water. The liquid in both flasks will probably appear slightly turbid, but the degree of turbidity will be the same in each. Standard silver nitrate solution is run into one flask until the slightest possible increase in turbidity is observed in comparison with the liquid in the other flask. This point is taken as indicating the conversion of the whole of the free potassium cyanide into the soluble silver salt, and therefore as determining the amount of available cyanide present.

The amount of gold in the solution is generally found by evaporating a known bulk with litharge, fluxing the residue and cupelling the resulting lead bullion. Evaporation on lead foil may likewise be employed.

Poisonous Properties of Cyanide.—A few words may not be out of place in this connexion. Although one of the most rapidly and deadly of known poisons when taken internally, its action as a blood poison is much less violent. Nevertheless, when introduced into cuts it produces very painful sores. The men employed in cleaning-up and in melting the slimes are subject to a peculiar eruption, especially on the arms, and complain of headache, giddiness, and general depression.

Ferrocyanide of potassium has been recommended as a remedy for the eruption; it may be taken internally and also applied as a lotion. Considering the dangerous nature of the reagent it is remarkable how few fatal cases have occurred through the use of cyanide on a large scale. In cases of poisoning precipitated carbonate of iron, obtained by mixing solutions of sodium carbonate and ferrous sulphate, may be used as an antidote, forming internally an insoluble blue compound with the cyanide.

Hydrocyanic acid acts directly on the nervous system, causing instant paralysis, hence any treatment which will excite the action of the nerves such as applications of cold water to the spine, inhalation of ammonia, etc., may be tried in cases of faintness produced by breathing the acid vapour.

The disposal of waste cyanide liquors is a matter of serious consideration. Solutions containing 0·1 to 0·2 per cent. of potassium cyanide must occasionally be discharged and are likely to contaminate the water of the dams or streams which receive them to a dangerous extent. If some effective means of precipitating the zinc, or better still of dispensing with the use of zinc altogether, could be devised there would never be any necessity for allowing cyanide liquors to leave the works.

Applications of the Cyanide Process.

Mr. Almarin B. Paul appears to have originated the idea of using cyanide solution in the battery crushing the ore wet. This he claims to have done with success at the Calamut mill, Shasta County, California. He states that his plan is in all cases to crush with a weak solution, and should the ore require a higher percentage of cyanide when the first solution has percolated below the surface of the ore, after the tanks have been filled, a stronger one can, if necessary, be introduced. All the dust and disagreeable effects of dry-crushing is thus avoided. The loss of cyanide in crushing is but nominal, and is off-set by the cheapness of working and completeness of distribution of the cyanide through the pulp in the tanks. This plan has been followed of late at the May Consolidated works in South Africa, but it does not appear to be applicable to all cases, as generally when ores have been crushed wet and run direct to the tanks the pulp has packed so hard as to be impenetrable to the leach liquor. Ores containing impurities, such as arsenic and tellurium, have proved obstinate to deal with.

The consumption of available potassium cyanide may for practical purposes be divided into avoidable and unavoidable decomposition; each of these factors varying with the composition of the ore, the strength of the solution, time of contact, and method of treatment.

Tests made on a heavy, raw sulphide gold ore by Mr. C. W. Merrill, using a 2 per cent. solution, showed that it was capable of decomposing available cyanide at the rate of 12 lbs. per ton in 24 hours, but that by taking all possible precautions this loss could be reduced to 3 lbs. per 24 hours.

The reduction in loss of cyanide seems, however, to have been set off by an extravagant loss of time, as it is necessary to continue the treatment for 7 to 10 days.

A series of extraction tests proved that a ¼ per cent. solution when reinforced each day gave as good results as a stronger one, and with a decomposition of only 5 to 7 lbs. of cyanide per ton. As the ore contained acid salts of iron and fine copper sulphides, both of which decompose potassium cyanide, the probability is that the weak solutions were rendered inert after a few hours' contact with the ore, hence the necessity of reinforcing them.

A series of experiments, published in detail in the *New York Mining Journal* of December 24th, 1892, were made by Mr. G. E. Kedzie, M.E., to determine how far the gold-bearing pyritic ores of Ouray, Colorado, could be successfully treated by the cyanide process, and also to learn the conditions under which the most complete extraction could be obtained, together with the amount of cyanide consumed. These experiments throw much light on the question of how far it is practicable to treat ores of a similar description by the cyanide method.

The samples under treatment contained gold and silver in varying proportions, ranging from 0·27 ounce to 145·90 ounces of the former, and 0·65 ounce to 458 ounces of the latter metal, the value of the high-grade ores and tailings being determined by triplicate scorification assays, and that of the low-grade ores and tailings by duplicate crucible fusions. The gangue in some cases was quartzose, in others calcareous or clayey, and contained iron pyrites, copper pyrites, and magnetite, either alone or in admixture.

The deductions drawn from these tests were: (1) the gold is more readily extracted than the silver; (2) under the same conditions the percentage of extraction is increased—(*a*) by the fineness of the pulp—(*b*) by the duration of treatment—(*c*) by the strength of the cyanide solution; (3) the greater the amount of cyanide added to the ore, the higher will be the percentage of extraction, but in this case the total values extracted for each pound of cyanide consumed are less than when a smaller amount of cyanide is used for each ton of ore treated; and (4) when the same amount of cyanide is used for each ton of ore treated the percentage of extraction is greater when the weight of the solution is equal to that of the ore taken.

His conclusions are that there are no flattering indications of the process being a metallurgical success with the pyritic ores under consideration. With high-grade ores, which are under no circumstances adapted to this process, the percentage of extraction under the most favourable circumstances is low, lower even than the results obtained by amalgamation. However, the total values extracted for each pound of cyanide consumed are relatively high.

With low-grade ores, even where the low value of the tailings will admit of their being thrown away, the total values extracted in a majority of instances are less than the cost of cyanide consumed, to say nothing of milling expenses. In these experiments the percentage of potassium cyanide varied from 0·5 to 1·5 per cent. The treatment lasted from 12 to 60 hours. The extraction of the gold ranged from 2·31 to 84·62 per cent. The extraction of the silver varies from *nil* to 88·88 per cent. The proportion of the potassium cyanide added per ton of ore represented from 5 to 60 lbs., and its consumption rose from 3·2 to 50·8 lbs. per ton. The lowest value extracted per lb. of cyanide consumed was 0·28 dollar and the highest 53·72 dollars. The latter result was obtained in treating an ore which assayed 145·90 ounces in gold and 458 ounces in silver per ton.

Mr. Kedzie suggests, as the outcome of his observations, that the strongest solutions used should not exceed in strength ½ per cent. of potassium cyanide, and good results are anticipated with much weaker ones. Arrangements should be made for the slow percolation of the cyanide solution, so as to keep the ore always in contact with a solution of nearly normal strength, and finally the period of lixiviation should be extended to 96 hours, if necessary, in order to secure a more complete extraction. To comply with these conditions the mechanical difficulties of leaching and loss of time must evidently be debited against a higher return.

Messrs. Clennel and Butlers state* that the cyanide process is the only method which has hitherto met with success in treating the tailings derived from various South African mills after amalgamation. The adoption of the process has been rapid, and its success most remarkable. Despite its simplicity on paper, the working metallurgist who attempts to carry out the process on a large scale soon finds himself confronted with difficulties. These arise from the nature of the material under treatment, and from the manipulations necessary in applying the treatment to ore in bulk.

Neither the solution of the gold in the ore under treatment, nor its precipitation, nor the conversion of this precipitate into bullion, is perfect

* Continuation of articles in the *New York Mining Journal* before referred to.

theoretically or practically. Losses occur in each operation, and the consumption of cyanide and zinc has been shown to be much in excess of what is indicated by the various chemical reactions primarily involved.

Hitherto the process has only been successfully applied to those ores or tailings usually described as free-milling, *i.e.*, such as are capable of yielding the greater part of their gold in the ordinary amalgamation process. The promoters of the process have been singularly fortunate in South Africa in the nature of the material they have had to deal with. The ores forming the upper portion of the main reef series, extending to a depth of 10 to 150 or 200 feet (as on the Robinson property) consist almost exclusively of silica and oxide of iron. They contain practically no substance, except gold and silver, which the cyanide is capable of attacking.

It is in dealing with ores or products containing sulphide of iron, especially when these are partially oxidized to sulphates and those containing compounds of lead, zinc, etc., that the difficulties of the process begin.

Solution of the Gold.—When the cyanide process was first introduced, about two years ago, it was thought necessary to agitate the material under treatment with the cyanide solution to obtain a satisfactory extraction. It was soon found, however, that the power needed and the rapid decomposition of the reagent were items of expense, which more than compensated for the greater percentage of the precious metals obtained in comparison with simple lixiviation. The operation is carried out by the African Gold Recovery Company, who represent the patentees in South Africa, as follows :—The damp tailings from the settling-pits are charged into wooden vats holding 35 to 50 tons, originally built square. The best works are now building them circular, those at the Robinson works holding 75 tons, and at the Langlaagte Estate 400 tons, whilst at the New Primrose still larger ones are being constructed.

The vats are filled to within a few inches of the top, and the surface of the tailings levelled. Cyanide solution of 0·6 to 0·8 per cent. strength is then allowed to flow into the tank until it is entirely filled.

The ore settles from 3 inches to 1 foot below the rim of the tank (the amount of shrinkage depending on the depth of the vat). This solution is allowed to remain undisturbed in contact with the ore for 12 hours.

Each vat is provided with a false bottom (usually a wooden framework covered with cocoanut matting). Below this is a layer of coarse sand and pebbles through which the solution percolates.

An iron pipe communicates with the vat below the false bottom, and conveys the filtered solution to the zinc boxes, where the precipitation takes place. After 12 hours' contact with the ore, the solution is allowed to drain out of the tank by opening a cock.

The dilute cyanide solution does not attack the wood, or corrode the iron piping to any appreciable extent. In wear and tear of the apparatus the use of cyanide, therefore, offers advantages over chlorine, which otherwise might be applied just as cheaply to the treatment of these oxidized surface-ores. Brass plungers and pump-valves are attacked, but not very rapidly. The pumps at the Robinson works stood for four months with comparatively little wear, but iron is preferable for the pump fittings where cyanide is employed.

As the liquor is drawn off during the leaching process it is replaced by fresh solution. This operation is continued for a longer or shorter period, depending on the grade of the tailings, for 6 to 12 hours. At the end of this period, known as the strong solution-leaching, a weaker solution (containing 0·2 to 0·4 per cent. of cyanide) is turned on, and allowed to filter through the ore for about 8 to 10 hours. This weak solution is then drawn off through another zinc box (known as the weak zinc box). Finally, a quantity of water is run into the tank, more or less equivalent to the amount of moisture which the ore contained when the tank was filled. This last washing-water displaces the weak cyanide solution, so that the volume of cyanide solution in use remains unchanged. The weak solution is in fact the liquor which has previously passed through the zinc boxes into the receiving-tanks or sumps, and has been pumped again to the leaching-tanks. The cyanide is usually supplied in cases containing 170 to 195 lbs. of crude cyanide, contaminated with carbonaceous matter and iron, but containing 72 to 78 per cent. of pure potassium cyanide.

This cyanide is usually dissolved in a small volume of water to form a highly concentrated solution, a special tank being employed for this purpose. The solution of required strength is obtained by adding this concentrated solution to the dilute liquor in the sumps. By this means a dilute solution of a given strength is more accurately arrived at than if the cakes of cyanide were dissolved directly in the required volume of water, since the percentage of cyanide can be more accurately determined in a strong solution. The actual amount of solution used is about half a ton of the stronger (0·6 to 0·8 per cent.) and half a ton of the weaker (0·2 to 0·4 per cent.) solution for every ton of ore leached.

When the final wash-water has been added, and has displaced the weak solution, the residues are discharged usually by the tedious process

of shovelling them over the side of the vat. A truck line runs generally by the side of the tanks to receive the discharged tailings, which are dumped outside the works. The tank is then ready for a fresh charge.

The percolation system just described may be modified however in various ways. One of the first difficulties arose when the tailings contained a small percentage of iron pyrites, which, on exposure to the air, had become converted into sulphate, with the liberation of free sulphuric acid. The trouble could be minimized by treating the tailings direct from the battery, giving no time for the oxidation of the pyrites, but to deal with old tailings which had been exposed to the atmosphere for some time it was found necessary to give them a preliminary washing, first with water and afterwards with an alkaline solution, such as lime or caustic soda. At the Robinson works lime was given the preference, as it is less active in inducing decomposition of the cyanide solution in the tanks and in attacking the zinc used in precipitation.

Substances present in the ore which are capable of decomposing the cyanide may cause much trouble by reprecipitating the gold, and depositing it in the gelatinous mass formed on the surface of the tank, especially if the circulation-method is employed. It has been stated that a ton of ore generally requires for its treatment a ton of solution, and since with free-milling ore a much smaller quantity is sufficient to dissolve the gold, it was suggested that the solution from one tank might be transferred to a second, and be made to dissolve an additional quantity before passing to the zinc boxes. For example, at the Robinson works it was found that 20 tons of solution were amply sufficient to extract 40 ounces of gold from 75 tons of tailings in one tank; whilst 20 tons of solution sufficed to fill a tank holding the usual charge of 75 tons of tailings, covering it to a depth of 3 or 4 inches.

Instead, therefore, of replacing this 20 tons of solution by fresh cyanide, the solution filtering through was continually pumped back again into the same tank for about 36 hours, and then passed through the zinc box.

The extraction of gold by this circulation-system was equal to that obtained by the ordinary method, and the consumption of cyanide was much less, since a much smaller quantity of solution was exposed to the zinc. Another modification suggested itself as a further step, viz., to transfer the solution charged with gold from one vat to a second and third in order that it might take up an additional quantity of gold from fresh tailings before going through the next stage of the process.

The advantages of this method are that the solutions from which the precipitate is obtained are much richer in gold, giving a cleaner deposit on the zinc with much less consumption of cyanide.

Whilst the usual practice is to prepare the cyanide solution in a special tank, as before stated, at the Robinson works, the strength of the liquor is kept up by adding cyanide in lumps, dissolving it under the stream from the pump. By this procedure, a cyanide solution, of required strength, is formed in the leaching-tank itself.

This simplifies the operation and diminishes the number of tanks needed, while affording an easy means of getting rid of the insoluble impurities of the cyanide (the so-called carbide of iron) which would otherwise accumulate as a black slimy deposit in the concentrated solution tank. This insoluble residue is, of course, discharged with the tailings when the tanks are emptied.

A further difficulty frequently encountered in the application of the cyanide process is the treatment of battery slimes, which, owing to their fine state of division have a tendency to agglomerate into pasty masses. These either resist the penetrating action of the cyanide or retain the dissolved gold during the leaching operation.

No satisfactory remedy had at any rate until quite recently been devised, though the evil may be lessened by mixing the slimes with clean, coarse sand. In the direct treatment of ore from the battery previously alluded to, coarse gold, which is easily caught on the plates, is very slowly dissolved by cyanide, and this is probably a serious source of loss.

The experience at the Langlaagte Estate and other works in treating pyritic concentrates with or without agitation seems to confirm what has been already stated. Although an extraction of over 90 per cent. has been obtained, it appears that the consumption of cyanide is enormous.

Various improvements have been introduced in the mechanical details of construction. The large leaching-vats of the Robinson works are rapidly and conveniently discharged by a trap-door placed in the centre of the tank bottom, which is hermetically closed by a screw-fastening. The enormous underground vats of the Langlaagte Estate works are discharged by a dredge, which appears to give satisfaction.

Precipitation of the Gold.—Having obtained a solution of gold in cyanide of potassium, the next step is to recover it. Various precipitants have been suggested, but the only one which has come into use on a large scale is metallic zinc in the form of freshly-turned shavings; zinc in sheets offer too little surface for the deposition. The same is true of granulated zinc. When once the surface has become coated with an extremely fine layer of gold the action ceases, or becomes so slow that the precipitant cannot be practically applied in this form. Zinc dust and zinc amalgam have also been tried and are effective, in so far as they

present a large surface for deposition, but are found to clog if the continued flow of liquid through them be interrupted. Sodium or potassium amalgam has been used with success on a small scale, as in the Molloy process now about to be tried with a 500 ton plant at the works of the Pioneer Gold Mining Company, but the difficulty so far has been to manufacture these substances cheaply and in sufficient quantity on the spot.

The zinc shavings now in use are prepared by turning thin sheets of zinc on the lathe. This produces a light spongy mass, which readily allows the solution to filter through and presents a large surface for the precipitation of the gold. These shavings are placed in wooden troughs, commonly known as zinc boxes, and the solution from the leaching-vats is allowed to flow slowly through them, depositing the gold as a finely divided black slime on the surface of the zinc, while the zinc gradually dissolves in the liquid. After passing the zinc box the exhausted solution, which should not contain more than ½ dwt. of gold per ton, flows into the storage tank or sump, whence it may be pumped back to the leaching-tanks, when a fresh charge has to be treated.

The simple replacement of gold by zinc is not the only reaction which occurs in the zinc box; we find that a notable falling off in the strength of the cyanide occurs, due to secondary reactions caused by the gold-zinc couple.

Various slight modifications have been introduced in the construction of the zinc boxes. They are usually divided into several compartments so arranged that the liquid flows alternately upward and downward through the shavings. The shavings are placed in a tray, the bottom of which is an iron-wire screen of about 4 holes to the inch. This is supported a few inches from the bottom of the zinc box. The fine gold slimes fall through this screen, and may thus be separated from the undecomposed zinc when the clean-up takes place. The zinc boxes used at the Robinson works are about 20 feet long, 2 feet wide, and 2 feet deep, with inclined bottoms. They are divided into compartments of about 20 inches in length. Each compartment holds about a bushel of shavings, weighing about 40 lbs.

Seven compartments in each zinc box are filled with shavings; a single compartment at the head is left empty to receive any sand that may be carried through the filters by the solution from the tanks. A double compartment at the foot is also left empty to allow any gold that may be carried away by the stream of liquid to deposit before the solution flows into the sump. About 60 tons of solution, which is the quantity required for treating the ordinary daily charge of 225 tons of tailings, are allowed to run off through two zinc boxes in about 9 hours. This solution may

carry from 1 to 3 ounces of gold per ton of liquid; after passing through the zinc boxes it rarely contains more than 2 dwts., and should not contain more than ½ dwt. if the precipitation has been properly carried out.

There are two sets of zinc boxes, one to receive the strong solutions (0·6 per cent. to 0·8 per cent. cyanide), and one for the weak solutions (0·2 per cent. to 0·4 per cent.). The slimes formed in the weak boxes are, as a rule, much poorer than those in the strong boxes, and less consumption of zinc takes place in them.

The total amount of zinc consumed amounts to about 100 lbs. per day. Two men are constantly employed at the lathes, so that the turning is an arduous and somewhat costly operation. It is desirable to use freshly-turned zinc, as the surface rapidly oxidizes and then becomes much less active in precipitating the gold. The most vigorous action of course takes place in the compartments which first receive the solution from the tanks. It is here that the zinc dissolves most rapidly, and is accordingly replaced by shavings from the lower compartments, whilst fresh zinc is continually added as the last compartment is emptied.

The clean-up takes place once or twice a month. The screens containing the undissolved shavings are lifted from the zinc boxes. The boxes are then left undisturbed for an hour or so to allow the zinc gold slime to settle at the bottom. The liquid is then drawn off by a syphon until very little is left above the slimes. The box is then cleaned out, and the slimes and muddy water allowed to drain through a screen of 40 meshes to the inch. The mass consisting of water, finely divided gold, and very fine zinc is rubbed through this screen with a short stick 5 or 6 inches long, to the end of which a piece of india-rubber is fixed.

The stuff remaining on the screen consists almost entirely of unconsumed zinc fine enough to pass through a screen of 12 meshes to the linear inch. This is replaced in the first division of the zinc boxes over a fresh lot of shavings. The slime consisting of finely divided gold and silver, with a large proportion of zinc and lead, and a certain quantity of tin, antimony, organic matter, and other accidental impurities, is allowed to settle in a small tank placed beneath the 40 mesh screen, and is now ready to undergo the drying and melting operations necessary to convert it into bullion.

In the Molloy process the use of zinc is dispensed with altogether. The solution passes through a shallow trough containing mercury, in which is an inner cylindrical vessel filled with solution of carbonate of soda, the edges of the cylinder just dipping beneath the mercury so that its contents are entirely cut off from the other portion of the vessel.

A rod of lead dips into the soda solution, the lead and mercury are connected with opposite poles of the dynamo and the solution is electrolysed by the passage of the current. The sodium released combines with the mercury to form sodium amalgam, which decomposes the gold cyanide solution with formation of gold amalgam, sodium cyanide being simultaneously produced.

It is claimed that much less decomposition of the cyanide takes place than with zinc, and that the outflowing solution is better adapted for dissolving fresh quantities of gold, becoming regenerated. In the ordinary method a large accumulation of zinc in the solutions must take place, which in time would render them valueless for gold extraction, whereas sodium cyanide is just as effective as the potassium compound. If this method of precipitation should prove successful on a large scale, a great improvement will have been effected.

Production of Bullion.—The third stage of the cyanide process consists in converting the precipitated gold into a saleable form. The slimes are transferred to enamelled iron pans and carefully dried over a small furnace. This is a tedious operation which requires time. The richness of the dried slimes will depend on the percentage of gold present in the cyanide liquors passed through the zinc boxes.

The pans in use at the Robinson works contain about 5 or 6 gallons of dried precipitate. This may contain as much as 150 or as little as 20 ounces of gold. The precipitate when nearly dry is mixed with sand, borax, and bicarbonate of soda, and melted in a No. 60 crucible at a fairly high temperature. The material melts very easily, forming a very liquid slag which, however, corrodes the pots rapidly, so that a good crucible rarely lasts out more than eight meltings. The change is not added all at once, but as each portion melts and sinks down fresh quantities of the mixture are added.

When the pot is full of liquid slag it may contain from 100 to 150 ounces of bullion. Large quantities of oxide of zinc are given off during the melting, which carry off a very appreciable amount of gold. The zinc fumes, together with the products formed by the decomposition of the cyanide salts, render the operation anything but healthy. The bullion produced is whitish in appearance and about 650 fine. It is very hard and brittle, and the bars are by no means uniform, so that it is difficult to obtain an accurate assay. In addition to zinc they contain silver, lead, and sometimes a little copper. Several ways have been suggested for obtaining a purer bullion. One method consists in partially roasting the slimes in a muffle furnace, whereby part of the zinc is oxidized and

volatilized, leaving a much smaller mass for subsequent melting. By this treatment bullion of 800 fine may be obtained.

Another method is to carefully wash out the soluble cyanide salts and then treat them with dilute sulphuric acid, which dissolves the zinc. The objection to this process is that the slimy mass is very difficult to filter, and retains the soluble zinc salts even after prolonged washing.

The same trouble occurs when the zinc is dissolved in hydrochloric acid. Some difficulty is also experienced in washing out the soluble cyanide salts. It is possible that the use of filter-presses might to some extent solve the difficulty of purifying the zinc slimes. The use of acid sodium sulphate also appears to promise good results as a solvent for zinc.

No attempt as a rule is made to refine the product, because to melt straight away into bars of bullion yields a larger number of ounces per month, though it does not augment the sterling value of the product.

In general it is found that on a large scale the extraction of gold by cyanide amounts to 70 or 80 per cent., and tailings assaying 8 to 10 dwts. will give residues assaying 2 to 2½ dwts.

A much higher extraction is obtained on a small scale with the same strength of solution when, relatively, large quantities of solution are allowed to pass through the material under treatment.

That the cyanide process is well adapted at present for the treatment of Witwatersrandt ores is shown by the fact that, although the system has been in use little more than two years, 40,000 tons of tailings are now being treated per month. The process is only in its infancy, the varied and complex problems to which it has given rise are mostly unsolved, its limits are yet undefined, and it would be rash indeed to forecast its future.

Turning again to what has been done in America, some interesting particulars of the process are given by Mr. C. Merrill in the *New York Mining Journal* of November 5th, 1892, from a report made by Messrs. Louis Jannin, Sen., and Henry Bratnober on the results of the process at the Mercur gold-mine, Fairfield, Utah. The ore is a siliceous limestone, carrying magnetic oxide of iron, traces of cinnabar, and gold (no silver). No free-gold appears to be present—in the ordinary acceptation of the term—though the magnetic oxide of iron appears to be more or less coated with a thin film of gold. The ore contains considerable silt, and any attempt at fine-crushing results in sliming the greater portion. This being fatal to successful leaching, coarse-crushing had to be resorted to, which has the disadvantage of involving more time for successful treatment. There appear in fact to be few ores which can be treated with any

degree of success unless crushed fine enough to pass a 20 or 30 mesh screen. The ore after crushing in a stone breaker passes through two sets of corrugated rolls, which give a product, 20 per cent. of which remains on a No. 4 screen, 40 per cent. on a No. 12, 13 per cent. on a No. 30, and 26 per cent. passes through. Of this last 26 per cent. nearly the whole is impalpable powder.

The ore is carried by an overhead tramway on cars to the leaching-vats. The best size and pattern for the latter, according to experience at this mill, is a round vat, the shell of which is No. 10 or 12 sheet-iron. The bottom is of 3 inch California red wood, and is caulked with oakum, over which is poured a mixture of tallow and resin. On this bottom are placed 1 inch by 1 inch slabs 18 inches apart. Upon this rests a false-bottom of 1 inch yellow pine, in every square inch of which is perforated a $\frac{3}{4}$ inch auger hole. Over this perforated false-bottom is stretched a burlap filter. There is, of course, a stopcock (between the true and false-bottom), which should be of iron. The dimensions of the vat are: diameter, 12 feet 8 inches; depth over all, 40 inches; depth to false-bottom, 35 inches; capacity, 14 tons. There seems no reason, however, why larger vats should not be used, provided they are round.

The ore having been charged, is levelled to within about 6 inches of the top of the vat, and the stopcock being closed, a $\frac{1}{4}$ per cent. solution (1 lb. of pure potassium cyanide to 400 lbs. of water) from the standardizing-tank, is run in from a pipe till about 3 inches of solution covers the top of the ore. It has been found that the solution acts slowly at first, but more rapidly after extraction has begun, possibly owing to some galvanic action.

The charge is allowed to soak from 12 to 24 hours, then the solution is allowed to percolate, flowing in at the top and out at the bottom for from 24 to 240 hours, according to the leaching rate of the ore. That from near the surface of the mine is very slimy and requires a longer time. The average time is about 60 hours, or practically until the outgoing solution does not discolour bright zinc. The test is made by placing a little sieve containing bright zinc threads under the stopcock, and allowing it to remain there for an hour or so.

If it remains bright the solution has extracted all that it will extract, and the flow is stopped. The outgoing solution from all the vats flows to a sump, and is pumped thence to a second or gold-solution tank. From this tank it is allowed to flow constantly through two boxes containing spongy or thread zinc, each box being 40 feet long, one of wood 12 inches square internally, and the other of iron 15 inches square. Each box is provided

with partial partitions which deflect the current from the bottom to the top and *vice versa*. These partitions are placed about 3 feet apart. The zinc should occupy so many of them as will give bright zinc in the last one, so as to ensure complete precipitation. The solution flows from the zinc boxes back to the standardizing-tank, where it is occasionally tested, and if below the required strength, potassium cyanide is added in proper quantities.

After the gold has been extracted and the solution has been turned off, the vats are allowed to drain. It has been found that there remains 400 lbs. of ¼ per cent. cyanide to the ton in the tailings, and to force this out a wash of about the same quantity (400 lbs.) of water is used, which joins the main body of rich solution in the sump.

After this is drained out, as the tailings still contain 0·3 to 0·4 of a pound of cyanide per ton, a second wash of 400 lbs. of water to the ton is added, and the very weak solution left (which is forced out), runs to the waste-solution tank, whence the first wash of succeeding charges is drawn.

At the end of the month the outlet from the gold-solution tanks to the zinc boxes is closed and the latter are allowed to drain. When comparatively free from solution the richest portion of the zinc product, which has the property of powdering up in the fingers, is removed.

Mr. A. Hanauer gives the following analysis of this zinc and gold product:—Zinc, 39·1; carbonate of lime, 36·7; gold, 4·4; cyanogen, 3·5; sulphur, 2·6; iron, 2·4; and residue, 6·0. This product is sampled and treated by the Omaha Smelting Company, who return 20·60 dollars per ounce of their assay of its gold contents. Deducting 12 cents for express charges, this leaves a net return of 19·88 dollars per ounce of gold extracted.

It is stated that from April 1st to July 1st, there were milled 1,513 tons of moist ore of an average value per dry ton by assay of £3 3s. 5d. (15·22 dollars). The ore tailings' assay was 10s. 10d. (2·60 dollars). The apparent extraction was therefore £2 12s. 7d. (12·62 dollars) per dry ton, or 83 per cent.; hence, without allowing for moisture, we should have a bullion return of 19,272·60 dollars. The actual bullion returns from the smelter were 16,805·80 dollars = 73 per cent. = £2 6s. 0d. (11·04 dollars) per ton of moist ore. The discrepancy is accounted for by the ore being weighed wet and assayed dry, making a difference of at least 6 per cent. due to moisture, besides loss by leakage, handling, and drying.

The losses due to leakage and handling will probably be minimized when the mill is in thorough working order, and should, it is claimed, leave a difference of not more than 2 to 3 per cent. The following is

[redacted] eration, and this process
[redacted] ally after a crude process
[redacted] rable losses of fine minerals,
[redacted] and in some few cases the
[redacted] nt in the form of amalgam
[redacted] g, therefore, it is safe to say
[redacted] material now treated of.

After [redacted] ules as a preparation for pan-
[redacted] nting the loss of quicksilver
[redacted] it is not so successful as is
[redacted] ise. The operation of roast-
[redacted] om its combinations, increases,
[redacted] d eliminates the objectionable
[redacted] effect on a large part of the gold,
[redacted] ndition unfavourable for securing
[redacted] to which the gold is thus affected
[redacted] pparently similar composition, and
[redacted] n influence on the result.
[redacted] of the roasted ores various methods are
[redacted] d in the colonies is by working with large
[redacted] water, and apart from contact with iron.
[redacted] iron pans seems in some cases much less
[redacted] mation is conducted in stone arrastras. The
[redacted] place of quicksilver, and the avoiding of contact
[redacted] found most beneficial in experiments conducted by
[redacted] and a high percentage was extracted from a low
[redacted]

[redacted] and, experiments on many gold ores in the New York
[redacted] gave unsatisfactory results by all these processes after
[redacted] ll reverberatory furnace, and nothing but chlorination
[redacted] ve when the material was rich in gold."
[redacted] nts the writer is perfectly in accord with the views that have
[redacted] d in regard to raw amalgamation, and entirely so in regard
[redacted] ediency of roasting first, if only because of the extra cost
[redacted] the process when the ore is roasted, which scarcely any ore can
[redacted] he believes that, in certain exceptional instances, as regards
[redacted] by locality, the process of raw-grinding is justifiable
[redacted]

[redacted] r. Foster pointed out in the discussion on
[redacted] is perfectly possible to extract a very high

percentage of gold from heavy pyritic ores and concentrates by this method, of which there are examples in the Pestarena ore in Italy (amalgamating it in Frankfort mills) and in some of the Transylvanian gold mines, where Tyrolean mills are employed for a similar purpose.

More frequently, however, one finds where an ore carries heavy pyrites it is not what one would term free-milling, and only a certain proportion, roughly speaking 50 to 65 per cent., can be got out by raw grinding, the process being generally accompanied by heavy loss of mercury and high working costs.

It is still more often the case, that mere grinding without previous natural decomposition (which can sometimes be assisted by adding a little salt to the ore pile and allowing it to weather for two or three months previous to treatment) will only extract a very insignificant percentage indeed, and roasting with salt generally will merely tend to make matters worse, both commercially and metallurgically.

The method of grinding, just alluded to, which is followed at Pestarena, in Italy, is in several respects unique, and cannot be passed over without special comment.

The ore, which consists of quartz, mixed with micaceous, graphite-schists, carrying iron pyrites, associated with a little arsenical pyrites, is first screened, and the lump ore, after being picked over, and if necessary cobbed, is crushed in a rock-breaker, and then delivered to Cornish rolls, whilst the screenings (mine fines) are trammed direct to the rolls, unless of too poor quality, in which case they are concentrated first by jigging.

The medium-size ore (resulting from cobbing) is washed and carefully picked over on tables, provided with settling-tanks to catch any fine pyrites that might otherwise escape, before it is sent to the stone-breaker.

The product of the rolls derived from these different sources is delivered to bins, connected with what are known as Frankfort mills, an improved form of arrastra.* 5 to 10 lbs. of lime per ton of ore is added to the charge to prevent sickening of the mercury. The action of sickening may be caused by greasy substances such as graphite, which, under the name of kish, is often used to cover the surface of castings, oil, grease, etc. Metallic oxides and finely divided carbonate of lead likewise cause flowing, and so do some soluble chlorides, owing to the formation of calomel on the surface of the mercury. Ferric-chloride being formed when ores are amalgamated in an iron pan with salt and sulphate of copper, will account

* The writer intends to make the construction and operation of these mills (for a description of which he is indebted to the kindness of Messrs. John Taylor & Sons) the subject of a separate paper, he will therefore pass over their description here, though of very great interest, without further comment.

for this action in some cases; where it is due to metallic chlorides a little metallic zinc added to the quicksilver will preserve it; when caused by graphite, which has been used to coat a mercury trough for instance, the only remedy is to carefully varnish it with shellac.

The quantity of ore treated in each mill varies from 10 cwts. to 1 ton per 24 hours, depending on the proportion of pyrites that it carries.

The report of the Pestarena company, for the year 1888-89, showed that 4,474·811 tons of wet ore, representing 4,345·443 dry metric tons, or 4,276·785 dry English tons, were milled in this way, at Val Toppa, during the 12 months ending June, 1889, with 20·5 mills, working 309 days. The results showed an extraction in bullion of 8 dwts. 23¾ grains, per English ton of ore. The bullion being 797·1 fine in gold, and 197·8 fine in silver. The fine gold, determined in the crude ore by assay, amounted to 8 dwts. 20 grains, per English ton, of which 7 dwts. 4 grains, were extracted by the mills, equivalent to a duty of 81·1 per cent., with a loss of 234 grammes of mercury per metric ton of ore treated.

The report of the same company for the year ending 1889-90 showed that 5,916·771 metric tons of wet ore, representing 5,724·004 dry metric tons, or 5,633·560 dry English tons, were milled at Pestarena (a separate establishment) during the 12 months ending June, 1890, with 25·9 mills, working 344 days. The results showed an extraction in bullion of 18 dwts. 8 grains per English ton of ore, the bullion being 742·4 fine in gold, and 252·2 fine in silver. The fine gold determined in the crude ore by assay, amounted to 17 dwts. 8⅓ grains per English ton, of which 13 dwts. 15¼ grains was extracted by the mills, equivalent to a duty of 78·77 per cent., with a loss of 230 grammes of mercury per metric ton.

Looking at these results, the question arises as to how far the extraction in grinding is affected by the fineness of the metal present entering into the bullion, the degree of concentration, and the grade of the ore, and it seems to lend confirmation to a point observed in other cases, that a low-grade ore, carrying fine metal (gold or silver) with a large percentage of gangue or sand in the concentrates, yielded in proportion a higher return than when these conditions are found reversed.

It may also happen that the loss of mercury is affected by the duty of the mills. The agents, Messrs. John Taylor & Sons, in their report on the Pestarena mines, for the year 1888, stated that the duty or percentage extracted of the assay contents of gold in the ore had increased, being 0·80 as against 0·78 last year; and the consumption of mercury had increased from 242 grammes to the ton during last year to 310 grammes per ton.

If the loss of mercury were due, as might be imagined, to the extra baseness of the ore, one would expect the yield to fall off, whereas the contrary is the case. The writer is inclined, therefore, to think that it may be rather attributed to extra grinding of the ore, which would tend to increase both the yield of gold and loss of quicksilver. Professor Le Neve Foster has remarked that on the whole more gold is extracted in these works in winter, when the water, coming from the mountains, is comparatively cold and clear, than when it is turbid and warm in summer. In July, 1887, for instance, at Val Toppa, the duty of the mills was 70·6 per cent., and varied from September to December from 91·7 to 88·5 per cent. Though it does not, in this respect, appear to follow an invariable rule in different years, this may be accounted for by modifying causes in different seasons, character of the ore and its general manipulation, as to amount of grinding, etc., and perhaps, as Dr. Foster thinks, the turbidity of the water, as well as the more rapid oxidation of the pyrites in summer, may partly account for these results.

The conclusion he draws that low temperature is not incompatible with good amalgamation in this instance, is no doubt perfectly true as well, since a certain amount of heat is generated by the mechanical action of grinding;* but of course this statement is not intended to apply to plate-amalgamation.

In Dakota, for example, where the thermometer sinks, at times, to 40 or 50 degs. below zero, provision is always made for heating the supply served to the stamps by passing the waste-steam of the engine through a steam-coil in the supply-tanks, and there is generally a steam-drum as well, running in front of the apron-plates, as an extra precaution.

Either very cold or warm water† would certainly be pernicious in plate-amalgamation. Speaking of the writer's own experience of grinding raw sulphurets in pans, he made some careful experiments in 1884, treating a quartzose ore, carrying on an average 2½ per cent. of pyrites, which was concentrated on end-bump tables. He put a lot (about 14 tons) through iron wheeler-pans, subjecting them to continuous amalgamation for 8 hours on somewhat the same plan as the American Boss system (so called after its inventor Mr. H. P. Boss), and found that though the concentrates originally assayed only 1 oz. 16 dwts. 18 grains, the tailings still contained 17 dwts. 12 grains per ton.

* Dr. Foster roughly measured the increase in temperature in course of grinding in a Frankfort mill at Pestarena, and found that an average rise of about 3° Fahr. took place, but on the mill-bed itself the heat must have been much greater.

† The-pan amalgamation of silver ores, it is true, is facilitated by a high temperature (live steam being often introduced to warm the pulp), but the conditions in that case are entirely different.

In the Black Hills, it has long been the fashion to treat blanket concentrates in pans. Dr. Hofman states* that when panned down for experiment, these gave 20·5 per cent. cleaner concentrates, assaying 40·18 dollars per ton, but when amalgamated in a wheeler-pan, only yielded 56·9 per cent. of their gold contents.

In Australia, again, the witer has constantly found that battery-pulp concentrated on percussion-tables and buddles, up to 60 and 75 per cent. of pyrites, when ground in berdan-pans, only yielded 50 to 60 per cent. of its gold in the first grinding, though about half as much more might be extracted by a repetition of the process at much extra time and cost.

The Warden in his official report on the Charters Towers gold-field for 1878, page 14, remarks in connexion with this subject: "There can be no doubt that in many instances more gold escapes with the tailings than is in the first instance obtained by the crushing mills. For support of this, I am aware of several hundred tons of tailings having been put through the stamper boxes as a trial, and the result obtained was 15 dwts. to the ton. If such a yield is obtainable in such a manner, I may well ask the question, what must be the yield of tailings when properly treated with the most approved gold-saving appliances? Practical men of long experience inform me that tailings† on this field, under proper treatment, will yield on the average 9 ozs. 5 dwts. per ton." The writer does not think that the average loss of gold at the present time in the pan-tailings of Charters Towers is much less, however, than 14 dwts. to the ton.

The only remedy that has been applied to any large extent is grinding and re-grinding. The re-grinding of these tailings (after the miner has relinquished his interest in them), was at one time a regular recognized business, and is doubtless still carried on to some extent at some of the mills.

This, no doubt, accounts for no small portion of the gold, indirectly supposed, if not alleged to be stolen by the miners working in some of the mines, or by the mill hands, an explanation the writer does not for one moment believe, though it may certainly be a convenient red herring to draw across the scent to divert investigation from channels it might possibly follow with more advantage to the general mining community and the industry at large.

There may be small isolated thefts of specimens, but, taken as a body, the writer has always found the Queensland miners an uncommonly honest set of men, and it is quite impossible that 18,593 ozs. to 15,169

* "Gold-milling in the Black Hills," by H. O. Hofman, *Trans. Am. Inst. Min. Eng.*, vol. xvii., page 538.

† The allusion here is evidently to pan-sludge after concentration and grinding.

ozs. (the excess of gold purchased by the banks over the mill returns in 1889 and 1891*) could have been illicitly obtained and secretly crushed.

As the mills do not publish any record of the gold got from the source referred to (that the writer is aware of), there is no check on the matter, and the miner who has an interest in a mine or claim (and there are few who have not) may more probably be the real sufferer,† whilst being branded actually as the culprit.

In pan-amalgamation, the flowering of the mercury which Mr. Curtis has alluded to, even when heavy pyritic concentrates are being worked, can generally be avoided with care, by selecting a suitable class of pan, grinding the ore to sludge before adding the mercury, and raising the shoes (if wheelers are used) off the bottom, during amalgamation (so as to allow the muller merely to act as an incorporator), keeping the pulp of the proper consistency (neither too thick nor too thin) and using chemicals judiciously, adapted to the particular conditions that obtain.

If the pulp gets too thick, the inevitable loss of mercury in treating ore in berdans is likely to be greatly intensified; using wheelers, the charge should be about the consistency of cream, and to avoid loss, the settler must be properly looked after.

A consideration of the MacArthur-Forrest process, also forces one to consider the losses of the precious metals, (more particularly gold in solution), that may occur through the indiscriminate use of chemicals, such as cyanide. Other re agents such as salt, iron, sulphate of copper, sal-ammoniac, and caustic soda and potash, are used by different mill-men, in certain cases, in the amalgamation of gold and silver ores.

Cyanide keeps the mercury quick and lively, and the last-named reagents neutralize greasy substances introduced into the pan, for which wood-ashes are also employed. Caustic lime is sometimes used with roasted ores which contain a great deal of cupric chloride, to reduce it to cuprous chloride. Sodium amalgam is useful, especially for ores containing binoxide of manganese, to prevent flowing, which that metal, as well as copper and lead, are more especially liable to occasion, by debasing the amalgam.

Blue-stone, salt, and iron assist the decomposition of certain silver ores, and an acid solution of the former salt, when there is a large proportion of clay in the ores, which causes it to ball-up and carry off globules of mercury, probably acts on the clay like alum, tending to promote its precipitation and prevent loss.‡

* *Charters Towers Gold Mines*, by L. W. Marsland, page 197.

† *Vide* remarks on page 404.

‡ Tenth Report, *Census of the United States*, 1880.

Dr. Raymond and others have frequently pointed out that some gold is lost in solution in ordinary plate-amalgamation, but if cyanide is the active agent in attacking gold and silver which it is represented to be, it stands to reason that very large hitherto unsuspected losses may occur in certain instances, especially when the gold is naturally in a fine condition.

We do not know how large these losses may have been in the past, because the writer ventures to say that there is no mill in the world where amalgamation-tailings are regularly tested for gold in solution, but if we have not examined the question hitherto, it is one that deserves to be looked into in the future where cyanide is used to any extent. A little red-oxide of mercury dissolved in the cyanide, will often greatly assist amalgamation, and for the recovery of the dissolved gold, a little zinc amalgam may be added to the pan towards the end of the operation.

Raw-grinding is still the favourite process in North Queensland, and it is likely to remain in fashion there for many years, for good reasons, or otherwise, although it has been proved to be a more or less mistaken idea.

The very fact that it pays local chlorination-works to purchase and treat the pan-tailings after the first grinding, shows that it cannot be otherwise than sheer waste of money with some of the Charters Towers ores to incur the first expense of grinding at all. Amongst the reasons alluded to may be mentioned :—

1. The heavy loss of capital involved in making a radical change in a field where all the mills are laid out specially for grinding, as the large number of pans which are now running would only be worth the value of old iron if they were thrown out; affording a good illustration of the importance of choosing the proper kind of plant in opening up a new district, making due provision for probable changes in the class of ore likely to be met with in depth.
2. The fact that some of the Queensland ores contain considerable amounts of base metal, especially lead, and these can be treated at some profit by grinding-milling, whilst it has yet to be determined how far this class of stone can be otherwise worked to better advantage; smelting being out of the question at present.
3. The difficulty of overcoming the general prejudice on a goldfield against any new form of procedure.
4. The fact that as many claims are worked by prospectors, and as many of the mills are run on custom-work, chlorination-works would have either to work a number of small lots separately, which would be costly and impracticable, or else buy the ore outright, which introduces the next difficulty.

5. That the miner, with a wisdom born perhaps of experience, likes to follow his gold and look after it himself from start to finish, and would not be convinced that selling it on assay the advantage did not gravitate to the side of the mill. It is only when he has followed it just as far as he can, and scraped every crevice of the mill himself (to see that there is not one atom of amalgam lost), that he is ready to let the tailings go out of his own control and sight.
6. A change would perhaps temporarily throw a small number of men, accustomed to grinding-milling out of employment, and introduce the necessity of specially skilled superintendence, so that any alteration in the existing *régime* might affect local capital and local management in these respects, and as the gold-fields policy of Queensland, when controlled by local influences, has up to the present turned apparently on the exclusion of everything British except money, the change is not likely to come yet awhile.

The chief sufferers, of course, are the miners themselves (who are mostly shareholders in the mines but not in the mills,) and outside capital introduced into the district, representing at present, the nominal amount of £1,737,268 out of a total of £3,774,400, invested in mines, in the colony of Queensland. Both the miner and capitalist are, it would therefore seem, paying to maintain a wasteful system, which benefits comparatively few people, by which the country loses a large amount of gold, which would be better in circulation in the pockets of the community, than in the river bottoms.

In districts, like Charters Towers, no doubt, we shall ultimately see most of the mills adopting the principle of simply catching all the free-gold they can in the battery and on plates,* concentrating thoroughly, and disposing of the pyrites to central chlorination-works, merely utilizing the pans as they stand for treating the tailings of the concentrators after they have been classified, whilst large outside mines, which have ample stocks of pyrites, will, in time, put up chlorination-works of their own with advantage; but smaller concerns will no doubt do best to stick to grinding and suffer the loss for the time being.

Where gold ores must be ground, it would be better, in the writer's opinion, to grind in Frankfort mills, or to substitute Chilian mills for

* A few pans might, of course, be kept for occasional use, to deal with ores that could be advantageously treated by grinding, under conditions described.

berdans, and amalgamate on copper plates outside, grade the pulp in classifiers, concentrate on efficient tables, and treat the concentrates by chlorination, or else where pans are employed for the treatment of sulphides (concentrates), to grind continuously in large-sized wheelers, with wooden sides (in place of the small iron ones that are in general use), and amalgamate afterwards with the mullers raised; or as another alternative, distribute the ground-up pan-sludge to berdans, discharging into large settlers provided with proper drags.

The writer's reason for this opinion is that even an ordinary wheeler* is a far faster grinder than a berdan, whilst the latter machine seems to be a better gold-amalgamator.

The writer ventures, however, to think that the statement that grinding in the colonies is the outcome of poor concentration, ought to be reversed, and for this reason, that a certain proportion of sand must be present to brighten the liberated gold and lighten the charge.

Another special point to observe is that a berdan grinds and amalgamates better, and naturally wears out less, if the drags are made of softer iron than the pan itself.

Hardwood drags may be used if the pan is intended simply as a machine to amalgamate and collect amalgam in. It is of course a first essential that the pan should be speeded right, and inclined at the proper angle from the vertical, depending on its diameter. The gold is amalgamated by the pan being allowed to run full for some time without overflow, water being afterwards turned on from a pipe to expel the ground-up sludge.

Eight berdans are about an ordinary allowance to a battery of five stamps (which crush on an average 2 tons per head per day) for dealing with the concentrates from the ordinary run of Queensland ore, carrying 2 to 6 per cent. of pyrites, though this allowance is often exceeded for re-grinding and treating extra heavy ores.

The cost of 32 berdans (the number we may assume on this basis that would be required) for a 20 stamp battery, including the shed to cover them, erected in running order at Charters Towers, would not be far short of £1,200 to £1,300, and the 32 pans would have a working capacity of something like 28 to 30 tons of sand and concentrates weekly, allowing, of course, for variations in the method of treatment, degree of concentration, and amount of re-grinding to be done.

* The writer alludes to the small cast-iron type in common use, not the wooden-sided combination pan used in silver-milling, between which and a berdan, in the matter of grinding, there can be no need for comparison.

The cost of this treatment may be estimated as follows :—

	Per Berdan. £	s.	d.
Wages per month	0	18	2
Wood "	0	11	10
Mercury "	1	2	9
Castings, wear of belts, etc., per month...	0	9	1
Handling sludge	0	3	3
Oil and chemicals	0	1	9
Total cost	£3	6	10

or equal to 2s. 6d. per day.

Assuming that each pan grinds about 3 cwts. per day (dry weight) of 60 per cent. concentrates, it is equivalent to saying that one pan grinds 201$\frac{3}{5}$ lbs. of clean concentrates per day, or 1 ton of pure pyrites in, say, 11 days, at an actual mill cost of £1 7s. 6d.* for a yield of 50 to 65 per cent. of the gold which the concentrates contain.

Taking the cost of the grinding plant (covered in) at £1,200, and reckoning interest on the spot at 4 per cent., we must add to the above costs £48 per annum, or 7½d. to 8½d. per ton of concentrates ground, equivalent to about 11½d. per ton of pyrites, making a total grinding cost of £1 8s. 5½d.† per ton of clean pyrites.

Looked at in another light, the actual working cost of grinding the Charters Towers concentrates in berdans may be reckoned at 2s. per crude ton, added to the ordinary milling-costs, in a 20 stamp battery with a duty as stated.

The Northern Miner of February 14th, 1889, gives an interesting account of a trial made at Charters Towers by Mr. Millet, a well-known miner, at the Mary Louisa mill, on an unusually heavy pyritic ore, from the 1 and 2 West Wellington mine. Eight tons were crushed as an experiment and yielded 4 tons 4½ cwts. of concentrates, 2 tons 4½ cwts. of which were taken for trial. This was distributed between the wheelers and berdans in the proportion of 1 ton 2 cwts. treated in the former, and 1 ton 2½ cwts. in the latter. The wheelers gave 2 ozs. 3 dwts., the berdans 2 ozs. 6 dwts. of gold. The berdan put through one wet ton per week, at a mill charge of £2, while the wheeler put through 5 to 6 tons, at a charge of £9, or about the rate of £1 12s. 9d. per ton, leaving a margin on charges in favour of the wheelers of 7s. 3d. per ton. The total extraction by milling and grinding‡ was 31 ozs. 14 dwts. from the 8 tons of stone treated, not counting the gold left in the pan-sludge, or the

* These figures are, of course, liable to fluctuate somewhat (up as well as down), depending on the relative percentage of sand, sulphides in the concentrates, and the actual percentage of the latter in the crude ore. † *Ibid.*

‡ Even with docile ores this seldom reaches more than 76 per cent. of the total gold in the stone at Charters Towers.

2 tons of concentrates left unground. If these latter had been ground the yield would doubtless have been increased by another 4 ozs., or an equivalent of about 4½ ozs. per ton.

As over 55 per cent of the total gold was got by amalgamation in the battery it would be extremely interesting to know what the pan sludge contained after grinding.

The extraction, it will be noticed, per ton of concentrates, was 2 ozs. 0 dwt. 20 grains with the berdan, as compared with 1 oz. 19 dwts. 4 grains with the wheeler, or a difference of 1⅔ dwts. in favour of the berdan, and valuing this gold at 3s. 5d. per dwt. it really represents a saving of 5s. 8d. per ton, off-setting the smaller mill charge employing the other pans.

Now, if we assume the above saving to be fairly representative (as regards the two methods of treatment), estimating the cost of operating the berdan at 3s. 5d. per ton in excess of the cost of the wheeler (an amount seldom exceeded in a 20 stamp mill), it will be apparent that the advantage to the mill owner, crushing stone of his own, under existing conditions, would rest on the side of using the berdan, as he would gain the difference between 3s. 5d. and 5s. 8d., netting a profit of 2s. 3d. per ton. As there are chlorination-works already established at Charters Towers we can further compare the cost of grinding with that of chlorination in this same district.

Mr. Brown, in a letter published in *The Northern Miner*, October 23rd, 1886, gives the cost of vat-chlorination as carried on by the North Queensland Pyrites Co., at the Burdekin works (of which he was formerly manager), as follows :—

Cost of roasting 15 tons of ore at Charters Towers in an ordinary reverberatory furnace :—

	£	s.	d.
Labour, 6 men	18	18	0
Firewood	7	16	0
Water	0	10	0
Salt	1	0	0
Kerosene	0	7	0
Total cost	£28	11	0

or £1 18s. 0d. per ton.

Cost of chemicals and labour chloridizing 26 tons of ore :—

	£	s.	d.
Management	6	0	0
Labour, 2 men	6	0	0
Water	1	0	0
Salt, 3 cwts. at 6s.	0	18	0
Manganese, 2¼ cwts. at 5s. 6d.	0	13	9
Sulphuric acid, 416 lbs. at 5s. 6d. ...	5	4	0
Sulphate of iron	1	10	0
Kerosene	0	5	0
Total cost	£21	10	9

or 16s. 7d. per ton ; making the total cost, £2 14s. 7d. per ton

The capacity of the furnace represented about the weekly capacity of the works, viz., 15 tons, and in the period ending September 1st, 1886, they paid 2s. in dividends* upon 740 tons of ore treated; £450 additional was invested out of profit in new plant, whilst the total capital cost of the works, up to the date in question, appears to have amounted to only £2,830 5s. The returns from the ore (pan-sludge) treated was 1,466 ozs. 8 dwts., or over 2 ozs. per ton. Owing to the success this trial plant had achieved it was proposed in 1886 to quadruple its capacity at an outlay estimated at between £4,000 and £5,000 additional, and Mr. Brown, in the letter previously alluded to, estimated that with an improved roasting-furnace† the time was not far distant when he would be able to treat a ton of ore at a cost of £1, working on a larger scale.

Mr. Brown goes on to say: "This field is exceptionally favourable for the establishment of extensive chlorination-works owing to there being a large percentage of float-gold, which is unfavourable for amalgamation, but is easily and perfectly extracted with chlorine. The time is close at hand when chlorine will do away with such extreme amalgamation as is now in practice, as the gold will be obtained much cheaper with that agent. Concentration is a matter which is much overlooked at present, and there is a large percentage of fine mundic passing off with the quartz-sand that could be easily saved by improved machinery, but this will not receive much attention until there is a demand for the concentrates, when it will be looked to. The large heaps of quartz-tailings, now looked upon as worthless, will be reduced to one-half their present value, and will pay handsomely under the chlorine process."

Now, if we assume on a liberal estimate that 80 per cent. of the gold in the pyrites can be extracted by a double grinding, and on a low estimate 85 to 95 per cent. by chlorination, we find that:—

	Per Ton. £	s.	d.		Per Ton. £	s.	d.
The cost of chlorination per ton of clean concentrates (page 407) amounts to	2	14	7	to	1	0	0
Add to this interest on a capital outlay of £2,800 to £7,800 at 4 per cent. on a capacity of 740 and 2,960 tons treated per annum	0	3	0¼	„	0	2	1¼
The total cost of chlorination is from	£2	17	7¼	„	1	2	1¼

Now, the cost of grinding per ton of clean concentrates has been shown to amount to £1 8s. 5½d. Therefore doubling this sum for re-grinding,

* On a nominal capital of £10,000, representing a net profit of £1,000 in eleven months, the year commencing August 12th, 1885, and ending September 1st, 1886.

† Which would reduce the cost of roasting to 10s.

the cost of obtaining 80 per cent. of the gold by this process, under the most favourable circumstances, will not be less than £2 16s. 11d., as compared with a yield of, say, 90 per cent. (to put it low) at a cost of £2 17s. 7¼d., under the most adverse conditions of chlorination.

If, in fact, we assume clean concentrates to run only 2 ozs. to the ton, the difference merely in yield at the average price of Charters Towers gold, will represent a money value of 13s. 8d. saved by chlorination, or a net gain of (13s. 8d. — 8¼d. =) 12s. 11¾d. per ton. With higher grade concentrates, and the costs reduced even to £1 10s. (as they easily ought to be), the gain with chlorination would be simply enormous. The question whether it is expedient or not to incur large gross cost in treatment for the sake of close extraction depends, in fact, not only on the quantities to be dealt with, but likewise on the grade of the material treated, it is evident that the richer this is the more important it becomes to save close.

With a single grinding, the results are scarcely less disadvantageous to the pan process, as the mine owner loses the difference between 65 per cent. and 90 per cent. of the gold in the pyrites, or, say, 10 dwts. per ton (worth £1 14s. 2d.), dealing with 2 ozs. sulphide ore.

The Charters Towers pyrites works, situated at Charters Towers itself, employ the vat process in the same way as the Burdekin works. The only peculiarities with regard to them are that they manufacture their own sulphuric acid on the spot, and employ a unique form of roasting-furnace—an idea which originated with Mr. D. A. Brown (who has been already alluded to), their able and energetic manager.

Mr. Brown conceived the plan of building his furnace on the side of a hill, possessing approximately the natural slopes requisite for the purpose he had in view, viz., to economize labour in manipulation and save as much fuel as possible (by utilizing the combustion of the sulphur in the ore, for roasting) without sacrificing the sweetness of the roast.

The furnace is shaped like a Fortschaufelung, with a number of doors on each side throughout its length.

To break up any lumps in the material (pan-sludge) to be roasted as it comes to the charging-floor it is first passed through a Carr disintegrator, driven by a pulley, provided with a coned friction-clutch. Below the disintegrator a hopper discharges the ore into three vertical circular openings, at the head of the hearth, each fitted with an Archimedean screw, driven by bevel-gearing. The speed of these screws regulates the feed, and delivers the ore into channels, which run down the upper part of the hearth.

Speaking from memory (as the writer has mislaid some notes he made when he visited the works in 1889), the hearth is about 600 feet in length, and has three different grades, commencing with 35 degs. at the head of the furnace, for a few feet, continued on for some 20 feet at a grade of 27 degs., and for the remainder of its length sloping at 18 degs. The fireplace and wrinkle (with working-openings on each side), back-up, and form the foot of the furnace.

Just below the brickwork of the hearth, three parallel lines of 6 inches fireproof stoneware pipes are laid the greater part of its length, connected at the two ends by bends, so that the artificial draught produced by a Roots blower, at the head of the furnace, circulates backwards and forwards three times through the pipe till it is finally discharged in a superheated condition, into the fireplace. The downpipe of the blower is provided with a gate-valve to prevent the furnace gases being drawn back into it when the blower stops.

The roof of the furnace is very low and flat, but presents a succession of 6 feet to 8 feet span transverse arches, with their curtains set crossways to the length of the hearth (which is about as wide as that of an ordinary reverberatory furnace) to throw the flame down on to the ore.

It was a bold project, which deserved success, though at first sight it would appear to be beset with many practical difficulties, in controlling the ore during its descent, so as to obtain a dead sweet roast during its gradual passage, from the top to the bottom of the furnace; and at the same time to avoid large losses in dust, not to mention difficulty, from the superheated gases entering the lead-chambers.

Still, from the fact that the furnace has been in active operation almost continuously from the time it was properly started, these objections would seem to have been overcome. Having lost sight of the matter lately, through pressure of various business engagements, the writer is unable to say what measure of success this system has actually achieved.

In making a preliminary trial of the furnace, Mr. Brown stated that he was able to roast 50 tons a week, with a consumption of 1 cord of wood to 10 tons of ore roasted, and he expected to increase this by some alterations that were in contemplation to 70 tons weekly without any increase in fuel burnt, anticipating that 1 cord of wood would be sufficient to dead sweet roast 15 tons of ore.

(*To be continued.*)

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,

HELD IN UNIVERSITY COLLEGE, NOTTINGHAM, DECEMBER 3RD, 1892.

MR. HENRY LEWIS, PRESIDENT, IN THE CHAIR.

The PRESIDENT, in opening the meeting, said that before commencing the business on the agenda paper he would like to state that a committee had that day waited on his worship the Mayor of Derby, and had asked him to kindly place at the disposal of the meeting of the Federated Institution of Engineers, which was to take place in the month of February, any accommodation that lay within his power. He had kindly consented to grant them the use of the Guild Hall for the meetings, and had also promised to assist in every way he possibly could to make the meeting a thorough success. The details of the arrangements for the meetings and excursion were in the hands of a very strong committee, and he hoped and trusted that they would have a very good meeting. It was also arranged for the Institution to hold a joint meeting with the members of the Midland Institute at Sheffield in April next, when he had no doubt they would have valuable and useful papers brought forward for discussion.

The SECRETARY read the list of new Members elected as follows :—

MEMBERS—

Mr. AUBREY GREGORY, Mining Engineer, Borrea Colliery, Barakár, E.I.R., India.

Mr. THOMAS YOUNG HAY, Colliery Manager, Whitwick Colliery, Coalville, Leicester.

Mr. FREDERICK LLOYD WARD, Colliery Manager, Unstone Colliery, Sheffield.

Mr. MATTHEW WOLSTENHOLME, Colliery Manager, Bestwood Park, Bulwell, Notts.

DISCUSSION UPON MR. M. DEACON'S PAPER ON "COMPARATIVE EXPERIMENTS UPON A CAPELL AND A SCHIELE FAN WORKING UNDER SIMILAR CONDITIONS."*

The PRESIDENT said the first paper for discussion was one by Mr. Deacon. If any gentlemen wished to comment upon it he hoped they would do so at once, and he would then ask Mr. Deacon to reply. He would take that opportunity of saying that a number of papers had been held back from time to time from one cause or another, and the Council had taken that into consideration, and decided that the discussion on those papers which were grouped together in the second paragraph must be closed that day. He would ask Mr. Deacon if he had any remarks to make.

Mr. M. DEACON (Blackwell) said he had not, except to say that the fan was working satisfactorily. They had not made any further experiments. In reply to the President he added that the Capell fan had been running a couple of years.

The PRESIDENT asked several gentlemen individually if they had anything further to add, and having been answered negatively he proposed a vote of thanks to Mr. Deacon for the very interesting communication. He was sure they were all indebted to him for his constantly bringing before them different papers interesting to those connected with collieries.

Mr. G. E. COKE (Nottingham) had much pleasure in seconding the vote of thanks.

Mr. DEACON acknowledged it suitably.

DISCUSSION ON THE "REPORT OF THE FRENCH COMMISSION ON THE USE OF EXPLOSIVES IN THE PRESENCE OF FIRE-DAMP IN MINES."

The PRESIDENT next alluded to the group of papers under various titles, expressed in the agenda paper as "On Explosives and Exploders," which had been brought forward from previous meetings for discussion. No remark was made until he mentioned the Report of the French Commission as above, when

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) said he had expected to hear some gentleman get up and say that he had read the Report of the French Commission all through. It was certainly one

* *Trans. Fed. Inst.*, vol. i., page 287.

of the longest and most important reports that had ever been issued to the members of the Institution. He did not know whether he stood in an uncommon position or not, but he had virtually read the report twice. It was such a valuable document that he would advise every member to try and spare time to read it. The French Commission had gone very elaborately indeed into the matter, and their report was well worth perusal. The members had now before them an important batch of papers, and he hoped they would be well discussed, because there were few things in mining of more importance than explosives and shot-firing. His own impression was that there was far too much shot-firing, and that managers of collieries did not sufficiently study the physical properties of the strata above and below the coal-seam, and that they did not take advantage of nature's forces, but used gunpowder and other explosives instead. If they only watched the working of the coal more, and brought the superincumbent weight to bear in the natural and most effective way, and managed their face of work accordingly, he thought there would be far less shot-firing. Men were very anxious, naturally, to use shots. He did not quite know the proportion between round coal and slack, but the getting price may be such that men would prefer shot-firing and quantity, if even slack was the larger proportion; in fact, they got quantity even if they did not get quality. But there was another matter to look at, viz., the condition of the coal when it got to the consumer. If the coal supplied had been got in the mine in a natural way, that is broken down by natural weight after being holed, it was despatched to the customer in the best condition. But if on the other hand it had been got by explosives, even if every caution had been used, the result at the colliery was coal shaken and friable, and it was broken by being loaded into the trucks. It received another shaking by railway transit, and by the time it reached the consumer's cellar, it contained a great proportion of slack. He thought there would be a far greater percentage of round coal placed in the consumer's cellar, and it would be far better for the consumer, if they did away with a great deal of the shot-firing. There was a point he noticed in Mr. Wallis' paper about the mode of firing shots.* There were a number of ways of firing shots in this district, some of them very antiquated, some of them very new, but it appeared to him that in mines worked by safety-lamps, the best method of firing shots was by electricity with low-tension fuses. Of course, in other mines worked by naked lights the firing was done indiscriminately, some with germans, some with fuses, and some with straws. He thought perhaps it was as well to close the

* *Trans. Fed. Inst.*, vol. ii., page 553.

discussion, as the North of England Institute had appointed a committee to investigate the matter; and as their report would appear in the Federated Transactions, it would come before that Institution and they would have another opportunity of discussing explosives and shot-firing. As regards explosives other than gunpowder, at the present moment he did not know that there was a single flameless explosive in the market. The French Commission told them that the best explosive was one whose explosive power was about half-way between the lime cartridge and dynamite, but he believed every explosive that had as yet been brought into the market had failed in its claim to be flameless; some had perhaps succeeded 999 times but had given flame the 1,000th, and one failure in an explosive was of far more value to know than 999 successes. There were gentlemen present who had much experience in the use of explosives, and they would no doubt be able to state that at the present moment there was no explosive on the market, that had not at one time or another failed in its claim to be flameless. He believed that the President was manager of a colliery drawing over 1,000 tons a day, in which a shot had never been fired of any sort or description. Another thing he might mention was that roadways were far better if the ripping and repairs could be done without shot-firing.

Mr. J. B. SMITH (Newstead) said, as regarded the report of the French Commission, he had not read the whole of it but had read parts. He was pleased to see one thing, and that was the interesting report on the action of coal-dust. They did not make coal-dust as dangerous as some gentlemen had said it was. They rather encouraged the idea that in the absence of gas they did not get explosions of coal-dust. He first studied that question in 1878, and since then had devoted much time to it, and his idea had always been that coal-dust itself was not dangerous *per se*, and that it was the molecular action of coal or any dust sufficiently light on the gas (fire-damp) round it which caused an explosion. He believed that other dust than coal-dust, if it could be made as fine as coal-dust, would give very much the same effects, and Sir Frederick Abel, of Woolwich, gave evidence before the English Commission, and stated that he found that many dusts, non-combustible in themselves, were capable of causing an explosion with a very small percentage of gas. There was also to be considered, in the case of blown-out shots, the gas distilled from the coal-dust, by heat.

Mr. T. A. SOUTHERN said he agreed to a very great extent with Mr. Stokes' remarks as to the possibility of shot-firing being very much reduced in mines where safety-lamps were used, and as to the advantage of

doing without it wherever possible. Mr. Stokes had called attention to the fact that there was no absolutely safe explosive, but he thought Mr. Stokes would agree with him when he attached to that statement a word in favour of explosives which are undoubtedly, if not absolutely safe, much safer than gunpowder. He thought it was desirable that nothing should be said to discourage the use of the safest explosives which were to be had, even though they did not give perfect safety.

Mr. M. DEACON (Blackwell) said it seemed to him to be a little incongruous to fire shots by electricity where explosives that emitted flame were used. At present, apparently, they had no explosive which was absolutely flameless, and if that was so it was a question how far it was necessary to use the method of firing by electricity. Where powder was in use, for instance, there could be no advantage in employing electricity, except that the place where a missed shot had occurred could be visited immediately the battery was disconnected. Electricity would be very much more generally used when they had an explosive which was flameless, and there were very few colliery managers who would not then adopt it. With regard to coal-dust, there had been two cases in which coal-dust had been enflamed where the question of gas could not arise. One was in a slack-disintegrator shed at the Barrow collieries, where a very distinct and important inflammation of coal-dust took place.* He did not know whether it could be called an explosion. Another was in the North of England, and of a somewhat similar character to that at Barrow.† It seemed to him that these particular instances went to show how some qualities of coal-dust might, under certain conditions, become explosive without the aid of fire-damp. He was of opinion that all coal-dusts were not explosive and that some were much more explosive than others. While it was possible that in disintegrating the slack for coking purposes gas might be given off and so assist in the inflammation of the dust, it seemed, as far as one of the cases under their consideration was concerned, that the dust came from some planks at a high level in the shed where it had been accumulating for some time, and if any gas had at any time been there it is fair to assume it would have disappeared before the dust was enflamed. As to the abolition of shot-firing in ripping, the majority of colliery managers would, he was sure, be only too glad to give up the use of explosives, as Mr. Stokes suggested, if they could see their way to do the work in an equally economical manner; but, so far as his experience went, there was very little ripping in the district that did not require some amount of blasting.

* *Trans. Fed. Inst.*, vol. iii., page 690. † *Ibid.*, vol. ii., pages 138 and 427.

Mr. J. B. SMITH thought the cases alluded to by Mr. Deacon rather supported the idea that coal-dust must have gas to cause it to explode. At the Barrow collieries he had alluded to, there was a roof on the disintegrator.

Mr. DEACON—That was so.

Mr. J. B. SMITH—Fire-damp would always go to the highest points, and it was well-known that charcoal or coal-dust would occlude a proportion of gas. The result of this dust being at the top of the disintegrator may have led to its being in contact with gas for a long time before it was knocked down, and he could not see that these cases could be used as evidence that coal-dust *per se* was inflammable.

Mr. STOKES was afraid, from what Mr. Deacon had said, that the remarks he had made about explosives were hardly quite clear. He did not suggest or mean to imply that gunpowder shots should be fired by electricity. If it were safe to fire gunpowder at all, they could fire it with what means they liked. His remarks referred to safety-lamp pits. There were a few pits still that used nothing but gunpowder, along with naked lights. As he had said, they had some explosives which would fire 99, or even 999 times and no flame. All credit to those gentlemen who had worked to bring about such a state of things. To them he said, "Go on and make one absolutely flameless." They had the water-cartridge which was very good and probably the safest mode of firing, but they knew that even that had failed. He was pleased to hear Mr. Deacon in describing coal-dust use the word "inflammation," and he was glad he did not use the word explosion. It was very gratifying to know that as yet the conclusion arrived at by the committee of that Institution on coal-dust, as set forth in their elaborate report of some years ago, had never been upset. In the accident Mr. Deacon had alluded to, he understood that two persons got into a large slack hopper with two flaming lamps, and one set about with a besom and swept the whole place. Of course the dust ignited, lifted the top off, and cracked some glass in the window. If they were to do a similar thing in a coal-mine and fire a shot they also would possibly have an inflammation. If they had taken the top off the hopper, the accident might not have occurred. As regarded coal-dust, let them find a mine—a dry and dusty one—in which gas had never been seen or known, and let them have an explosion taking place in such a mine. If they did get an explosion he ventured to think it would convince more persons than all the discussion and experiments. All the mines in which explosions had taken place had, unfortunately for the dust alone theory, contained gas, and very plentiful gas in many of them. Mr. Deacon had

spoken about ripping, and thought some kind of explosive must be used for such work. He had himself mentioned a pit which had been working many years and drawing 1,000 tons.

The CHAIRMAN—2,000 tons.

Mr. STOKES—2,000 tons a day, in which not a single shot had been fired for ripping or other causes. He thought that was as good a reply as he could give to Mr. Deacon.

Mr. SOUTHERN said that in asking them to name a colliery containing dry dust in which fire-damp had never been seen, and in which there had been an explosion, Mr. Stokes asked them to perform what was practically an impossibility. They must be very deep mines for the dust to be very dry, and there were no deep coal-mines in which fire-damp had never been seen. In supporting what Mr. Stokes had said with regard to the reduction in the number of shots fired, he quite agreed with Mr. Deacon that there was a great deal of ripping which could not be got down without shot-firing. Where rock-ripping was necessary he did not see that it could be done by any other means except by blasting, but he had seen many cases where shots had been fired wholly unnecessarily, and where he was sure Mr. Deacon himself would not have used them.

Mr. DEACON did not for one moment wish to say that all ripping required shot-firing. He thought if they could find some other method of getting it down economically they would be very glad.

Mr. STOKES said, in reply to Mr. Southern, who contended he had set them an impossibility, he might instance lignite-mines.

Mr. SOUTHERN—Are they deep?

Mr. STOKES said they varied in depth, but they were drier than most coal-mines. Although worked with naked lights, an inflammation of dust had never been known. Lignite-dust was plentiful in some mines, and very inflammable; but both gas and explosions were unknown.

Mr. G. J. BINNS asked Mr. Stokes if he could give any particulars of the composition of the lignites referred to? because he was personally acquainted with a coal which might be classed as a lignite. It contained 14·61 per cent. of water. Would that bring it within the classification adopted by Mr. Stokes?

Mr. STOKES could not remember.

Mr. BINNS said the coal he referred to, resembled in some respects lignite, but it had not the woody structure apparent in true lignite. It was, at the same time, not a true coal, but distinctly a brown coal. At one of the collieries where it was found, in New Zealand, in 1879, a very disastrous explosion occurred, killing every man in the workings—34 of

them. Fire-damp had been found in the mine. He knew at the time it was stated—he gave it for what it was worth—that the mine was not a lignite-mine, because fire-damp was never found in a lignite-mine. It undoubtedly was a brown coal or a pitch coal. Whether the German lignites were similar to this he did not know, but his recollection of what he had seen was that they were browner. Since the explosion the mine had been worked with safety-lamps.

Mr. ALFRED CHAMBERS (Nottingham) thought that sufficient interest was not taken in the coal working of a colliery. There was often too great hurry shown in working, too far in advance, narrow widths of coal with fast ends to the right and left, thereby losing the natural advantages of the superincumbent strata, and causing extra blasting. Knowing the exact bearings of end and face, and also the line giving the best results in large coal, a district of considerable width might be worked to a theoretical line by, at short periods, checking advanced points, and concentrating men in the portions behind. Strong coal gave increased safety in spragging, better roof, by giving support to the roof while being holed, and facilitated methodical working.

The PRESIDENT, in summing up the remarks, said Mr. Stokes was perfectly right in stating that at Linby colliery during the last sixteen or seventeen years there never had been a shot fired in getting the coal, and to a great extent that was to be attributed to the way the colliery was laid out in the first instance. The superincumbent strata act as a lever. The face was something like 1½ miles long without a single cutting, and any practical man would understand that the overlying strata worked in assisting the men to get the coal. When shot-firing many years ago they employed electricity. The fewer shots they had to fire the better, and the sooner germans, straws, and fuses were done away with the better. He proposed a vote of thanks and closed the discussion. He hoped the remarks of Mr. Stokes and other gentlemen would bear good fruit. They had given them some idea how to do better as regarded blasting.

Mr. H. R. HEWITT (Derby) seconded the vote of thanks, and said they had been given some very valuable information, and had had a very good discussion on previous occasions as well as on that day.

The vote was carried unanimously.

DISCUSSION ON MR. J. C. B. HENDY'S PAPER ON "THE STANTON IRONWORKS COMPANY'S COLLIERIES."*

The PRESIDENT said Mr. Hendy had written a very interesting paper, and their outing at Stanton Ironworks collieries was very enjoyable; he hoped that on some future occasion they would have another such excursion. He proposed a sincere vote of thanks to Mr. Hendy.

Mr. T. A. SOUTHERN had very great pleasure in seconding the vote, more especially as he had had occasion to make some remarks upon the paper.

The vote was carried unanimously.

DISCUSSION ON MR. M. DEACON'S "NOTES UPON A SMALL ELECTRIC PUMPING PLANT."†

Mr. DEACON said the plant had now been at work for twenty-two months, and during that time had given great satisfaction, and they had had no trouble with it. As to the cost of repairs, he could now give a few figures. During the twenty-two months the plant had cost in repairs £10 3s. 10d., made up of new switches, additions, new brushes, and new belt, and the labour attendant on such repairs. The motor was in excellent condition, very slightly worn, and he thought they would get many years' work out of it yet.

The PRESIDENT asked what amount of water was dealt with?

Mr. DEACON replied that they were pumping 40 gallons a minute during the time it was working, which was only four hours per day.

The PRESIDENT asked how far it was from the pit bottom?

Mr. DEACON—About a mile.

Mr. SOUTHERN asked the height the water was raised.

Mr. DEACON replied it was a very small head, but this seemed an economical way of getting rid of water in dip workings. The annual cost now was £70, including fuel. Before it was a very heavy item.

The PRESIDENT said, perhaps some other gentlemen, labouring under similar difficulties, would give their experience. He knew what a nuisance it was to pump water 1½ miles from the pit bottom.

Mr. DEACON said the motor was one of the enclosed motors—Messrs. Stokes and Davis. They did not find the wear was any more than in the case of the commutator being outside.

* *Trans. Fed. Inst.*, vol. ii., page 531. † *Ibid.*, vol. iii., page 191.

Mr. STOKES said there were a few questions which he was sure would be very interesting if Mr. Deacon would answer them. As to the wear and tear of the commutator, Mr. Deacon had answered that. In carrying the wires from the dynamo on the surface down the pit to the motor a mile away from the pit bottom, what about breaking and sparking? Mr. Deacon was working an electric motor in a safety-lamp pit. It was doing very good work. Had he had to take down compressed air for the purpose, he would have had to put in a long length of pipes and to put down a very expensive plant. By using the dynamo for lighting at the top and pit bottom, when required, and pumping water when not used for lighting, there was a double use made of the dynamo. He would like to know if Mr. Deacon had any suggestion to make or improvements to point out based upon his experience? Would he recommend placing the wires in wooden troughs or pipes and burying them underground, or if not how did he obviate short circuits or sparking in case of breakage? Would he carry the wires on pulleys or on the timbers of the roof? Again, Mr. Deacon was the first who had placed one of the new enclosed motors to work. Members would like to know if it were working satisfactorily, if it were safe, if it had ever failed, and also how the motor was fixed. Could it be lifted about easily, or was it a fixture. There were a number of other queries which arose, and he hoped other gentlemen would ask further questions. He might say there was a pumping plant put down in the district which they told him was a failure—a complete failure—and why? It was found out by an electrician what was the matter. He said "you have short-circuited the current and it is never likely to work." That was a failure, certainly; not a failure of the motor, but due to a want of scientific knowledge on the part of the manager.

Mr. C. J. OLIVER (Chesterfield) said a window of talc was placed in the commutator disc. Was this safe in case of an explosion inside the commutator?

Mr. SOUTHERN asked Mr. Deacon to tell them decisively and emphatically, from the experience he has had in this case, whether he considered this mode of transmitting power was under similar circumstances the best?

Mr. G. E. COKE asked whether the electric pump could be depended on to work continuously, and if it required unusual care? He should be glad to know if it was the kind of plant Mr. Deacon would recommend for a small colliery without first-class enginewrights and mechanics to look after it?

Mr. DEACON replied in answer to the first remark of Mr. Stokes as to

burying the cables, all he could say from his experience was that they had had no difficulty with the cables, which were carried on pot insulators fastened to the timbers.

The PRESIDENT—Like an ordinary signal wire.

Mr. DEACON—Yes, but farther apart, about 10 or 12 inches. He did not know that it was necessary to put the cables underground, but it would be a precaution which it might be advisable to take, and if he put down a plant with a high voltage he should feel inclined to box and bury them. At Shirland they only worked up to 120 volts, and he did not think it was necessary with such a low voltage to bury the cables. The reason for the low voltage was that the dynamo was used both for pumping and lighting, and the low voltage was adopted as being more suitable for lighting. With regard to breakdowns or failures, they had never had either. They had had stops of 10 or 15 minutes, but he could safely say that they had never had anything which had been reported as a failure. The pump was fixed on a pitchpine frame, which could be easily moved from one place to another. His original intention was to put it on tram wheels, but he found that the pump plungers were so far apart that it would be rather inconvenient to take it round sharp curves on wheels. He found it more convenient to put it on a light frame and move it when occasion required. He had moved it once. If the plungers were placed close together, there would be no difficulty whatever in taking it about on wheels. With regard to Mr. Oliver's question as to the safety of the motor in case of an explosion occurring inside the commutator, he believed such an explosion was impossible, as the flame-tight joint had been experimentally proved to be gas-tight. He submitted the motor to experiments, of which he had given particulars in his paper. They were very severe tests. In these tests they were unable to cause an explosion inside the commutator although the brushes had been so set as to cause violent sparking. There was a little talc window in the end of the commutator, and through it they could see the violent sparking. The talc window was broken so as to admit the gas into the inside, and they got an explosion immediately. He thought there was no likelihood of the window being broken accidentally. It was so small, and of such a shape and in such a position, that a fall would not be likely to break it without breaking the commutator itself, and thus stopping it and the sparking. Mr. Southern asked whether he considered this the best method of transmitting power. He thought that depended on the conditions of each particular case. When they had a number of twists and turns in the roads and a long distance to traverse, he thought this system would be found to be the best means of trans-

mitting power. But he was not prepared to say that it was superior to other methods in all cases. He was of opinion that for a certain distance and with straight roads, rope-power would be more economical, but what that exact distance was he could not say. If they wanted the power a mile away there was no doubt that electrical transmission was more economical than rope, unless a rope was used for haulage purposes, when it might be more economical to utilize the rope for pumping or other work. With reference to Mr. Coke's question, he did not see anything so difficult in the management of electric motors that a man with ordinary intelligence would be incapable of overcoming, after a small amount of experience and instruction from an electrician. He did not see any reason why it should be more difficult at a small colliery than a large one. The man at the small colliery would have more time to attend to it himself, whilst at a large colliery the work was often necessarily deputed by the head enginewright to his assistants.

Mr. J. C. B. HENDY (Pleasley) said that at the Silverhill colliery they had a small electric pump, something like Mr. Deacon's, for the purpose of draining some dip workings at a considerable distance from the pit bottom. The pump and motor were fixed to a frame on wheels, which was a convenient arrangement, as the pump could thus be moved about the mine on the ordinary tram roads to any desired point. An extra length of cable was allowed to enable the pump to be moved forward as the water was lowered. With respect to the cables, they were taken down the shaft in wooden casing, but in the workings they were buried in the floor and not fixed on to the timbers or props, the reason for this being that, as the pit was a new one, the timbers were constantly requiring to be renewed, and if the cables had been fixed to them they would probably have been damaged through the crushing or weighting of the road. In answer to the President's question as to the Pleasley electric plant, this plant was at present used entirely for haulage. In addition to the large motor which was bringing 500 tons of coal a day to the pit bottom, they had recently started a small motor which was working an endless-rope about 600 yards long, and which had done away with six large horses, and they hoped soon to start another motor in a different part of the mine to work another endless-rope 600 or 700 yards long. They would then have three motors in the mine, all driven from the one dynamo on the surface, the current for the small motors being simply taken by branch cables, spliced to the main cable near the bottom of the shaft.

Mr. STOKES said there were two points which at present had not been touched upon, one was the cost of copper wire. If the current were con-

veyed a long distance, would not the cost come to a considerable amount, had Mr. Deacon tried to use old wire ropes? In taking electricity down the pits why could not the old winding and haulage ropes be made to convey the electric current? If put in a box with coal-dust and tar, he believed they made a splendid conductor of electricity, and being of large sectional area there was very little loss in current or voltage. They had been discussing the question of motors for pumping, but motors could be used for haulage or other purposes. Sometimes the workings of a mine came to a place where, owing to a fault or a dip in the seam, it was difficult to get horses to bring the tubs up. They could, at such a place, put up a motor and haul, as well as they could do the pumping.

Mr. DEACON, in answer, said a good deal depended on the cost of the cables. In their case the cables were rather costly, because it was more economical for lighting to use a low voltage than a high voltage. He had no experience in using old ropes, but one objection was that the conductivity of iron was about six times less than copper, and the insulation of wire ropes appeared to be a matter of some difficulty.

Mr. J. B. SMITH said he had a talk the other day on this question of using wire ropes, with a gentleman who was taking electricity something like 1,500 yards by means of wire ropes, and who said he could detect no leakage whatever, and that he found coal-dust was almost as good an insulator as india-rubber. With regard to the cost of cables, he was asked by a friend of his the other day as to conveying power 200 yards, the estimated cost of the cables being £540. He recommended him to try an experiment at a cost of £30 or £40 by using old pit rope.

The PRESIDENT asked if, by the old flat rope, he meant the whole of it, or one or two strands?

Mr. SMITH—The whole of it; and put at the ends strips of copper, and unite them to the wire rope for attachment to the other wires. The wire rope was laid in boxes filled with coal-dust.

Mr. SOUTHERN—Does that apply to wet coal-dust?

Mr. SMITH—No, dry. He put them in boxes and covered them with pitch.

The PRESIDENT said there was no doubt that electricity applied to mining was as yet only in its infancy. Winding, hauling, and pumping would no doubt eventually be done by electricity. The different papers had shown the small beginnings, and were most useful to the members of the Institution. He had great pleasure in proposing a vote of thanks to Mr. Deacon.

Mr. HENDY seconded the vote, and it was passed with acclamation.

DISCUSSION ON THE REV. G. M. CAPELL'S "NOTES ON FAN GAUGES IN CONNEXION WITH FAN TESTING AND THE ADAPTATION OF FANS TO MINES; AND COMPARISON OF FAN AND FURNACE AT SILVERHILL COLLIERY."*

Mr. J. C. B. HENDY said he would like to make one or two observations on this paper. He referred first to Mr. Capell's remarks on page 199, where he (Mr. Capell) compared the quantities of air and water-gauge obtained with the furnace, with those given by his fan. So far as the fan was concerned, the results were no doubt fairly satisfactory, but in justice to the furnace he must say that the figures Mr. Capell had taken did not by any means represent the amount of work the furnace really did. In calculations such as Mr. Capell made, of course everything depended on the initial gauge, and he took the gauge for the furnace at 1·40 inches for a quantity of 110,000 cubic feet per minute. Now, he would point out that they frequently got as much as 130,000 cubic feet per minute with the furnace, with a water-gauge of 1·40 inches in the mine; and with a gauge of only 1·10 inches they regularly obtained from 110,000 to 120,000 cubic feet per minute with the furnace; these varying amounts being doubtless due to the difference in the temperatures, and the conditions of the mine or furnace when the several measurements were made. So that, if we take 125,000 cubic feet per minute obtained with the furnace, and a water-gauge of 1·40 inches, and make a similar calculation, with the square of the volumes, to that of Mr. Capell, we would have, after adding 0·90 for shaft friction, a water-gauge of 4·48 inches for 200,000 cubic feet per minute with the furnace instead of 5·52 inches. Again, if we take the lower gauge of 1·10 inches and 115,000 cubic feet per minute, this gives a gauge of 4·22 inches including shaft friction for 200,000 cubic feet, which is about the same as that of the fan. Each of these examples gives a gauge of over 1 inch less than that of 5·52 inches arrived at by Mr. Capell for the furnace. Of course, in comparing a fan with a furnace, the variations of temperature and barometric pressure were most important; and it was impossible to make reliable comparisons unless the conditions as to these were precisely similar, or allowance for these variations were made. 100,000 cubic feet of air at 40 degs. Fahr. was increased to something like 120,000 cubic feet at 80 degs. Fahr., and in a deep pit a furnace might be expected to give a comparatively better result with a low surface-temperature than a fan. Mr. Capell spoke of one of

* *Trans. Fed. Inst.*, vol. iii., page 196.

his fans working in Belgium and following on a furnace, but he did not give the shaft friction nor the difference in this case between the water-gauge of the furnace and that of the fan. If he would give these data they would be very interesting.

Mr. SOUTHERN asked Mr. Hendy how Mr. Capell had arrived at the shaft friction he gave in his paper? Had he done it by taking the two gauges, in the fan-drift and on the underground doors, and subtracting one from the other.

Mr. HENDY said he had subtracted the gauge in the mine from that in the fan-drift, and this he added to the furnace-gauge.

The PRESIDENT said the Council had had a letter from Mr. Capell before them in which he regretted that business on the Continent prevented his being present, but the Council thought it better to close the discussion on that paper. Mr. Hendy's remarks in due course would come under the notice of Mr. Capell, and he would be able to reply in another short paper if he thought necessary.

CORRESPONDENCE.

The Rev. G. M. CAPELL wrote that he took the mean of figures given him by Mr. J. A. Longden and Mr. Hendy for the furnace performances.* It was difficult for an outsider who had not measured the air to do more than deal with the figures laid before him. Under date of March 2nd, 1891, Mr. Hendy kindly supplied the following notes as to the furnace work at Silverhill :—

Surface barometer, 29·50 inches; thermometer, 52 degs. Fahr. In pit, barometer, 30·83 inches; thermometer, 64 degs. Fahr.; water-gauge, 1·40 inches.

Split of Air.	Volume. Cubic Feet.	Water-gauge. Inches.
North	12,600 ...	·35
North-west	10,850 ...	·60
North-north-west ...	4,500 ...	·30
South-south-west ...	15,300 ...	·20
South	18,000 ...	·80
North-east	8,160 ...	1·00
Stables	6,000 ...	—
Main north	13,020 ...	1·00
Main south	17,100 ...	·30
Total	105,530	

* *Trans. Fed. Inst.*, vol. iii., page 198.

Mr. J. A. Longden mentioned 110,000 feet as the furnace work at 1·40 inches water-gauge. So the writer thought he fairly put the furnace work at 110,000 feet at 1·40 inches. Mr. Capell never before heard of a gauge of 1·10 inches with 115,000 feet. Mr. Capell also noted that in the same letter from which he quoted, the furnace showed 105,530 cubic feet at 1·40 inches water-gauge in the pit; the measurements with the fan with 1·00 inch water-gauge in the pit, and presumably with the same gauge as in the furnace trials, air being measured at the same places, gave 97,040 cubic feet, the bank gauge of the fan being 1·40 inches. Mr. Capell has just found this letter dated December 19th, 1891; and he hoped this will make it clear that he was not "writing in the air" when he penned his paper. The reference to a fan in Belgium at Grand Hornu colliery, was to a 12½ feet fan which superseded two Lemielle ventilators, each 19·28 feet in diameter, and not a furnace, as there are none allowed in Belgium. The fan was guaranteed to give 109,800 cubic feet at 10 inches water-gauge. It actually gives 163,000 feet at 9 inches water-gauge. The shaft friction given was the actual friction shown by the fan. Theory would make it higher for 199,500 cubic feet in the Silverhill upcast and downcast shafts. In reply to Mr. Southern's remark* that back pressure should not be deducted in calculating net work, Mr. Capell begged to submit this case. Suppose steam is admitted on a piston, on the other side of which was a spiral spring, which on being compressed represented half the pressure shown on the diagram, would it be fair to say that the diagram showed the work on the crank pin of the engine? Unless Mr. Capell was mistaken, back pressure acts exactly like a spring in compression, and shows more work in the diagram than is really transmitted to the crank pin. If his theory is wrong, he will be most pleased to have the matter elucidated. In a later diagram with no back pressure, at 28 revolutions, and ⅛ cut-off, water-gauge on the fan being 1·40 inches, Mr. Hendy returned a diagram worked out, showing 55·9 per cent. useful effect on the Silverhill fan against 46 per cent. in the published account of his trials of the Silverhill fan, which seems to support the theory put forward as to back pressures. By simultaneous use of two indicators, one at each end of the cylinder, some light might be thrown on this question.

Mr. G. J. Binns then read the following paper on "An Improved Head-gear for Pit Horses," and exhibited the head-gear referred to:—

* *Trans. Fed. Inst.*, vol. iii., page 1005.

AN IMPROVED HEAD-GEAR FOR PIT HORSES.

By GEORGE J. BINNS.

Owing to its delicate construction and exposed position, the eye of a horse is at all times liable to become damaged, and the restricted space in which it is often necessary for a pit horse to turn, added to the rapidity of movement which is frequently requisite, makes accidents of this nature somewhat usual.

A certain amount of protection in most cases is afforded to the frontal region by a pad extending from between the ears over the forehead, but this does not provide the slightest shield to the eyes, and in order to give this protection the writer has designed the head-stall which he now ventures to bring before this Institution.

The contrivance consists of an ordinary bit and bridle, the latter, however, made principally of a solid piece of leather, extending vertically from the frontal strap to the nose-band, and laterally from one cheek strap right across the face to the other. This is fastened on in the usual manner, and is provided with the customary frontal pad. Ventilation is provided by a few perforations, and the eyeholes, which are of the requisite dimensions, are furnished on the upper side with a semicircular guard of thick leather which covers the protuberant bone immediately above the eye, and affords considerable protection to that organ.

Of course nothing short of a complete cover will prevent a deliberate thrust from penetrating, but by the appliance now described, unintentional injury will no doubt frequently be averted. The bridle is but little dearer than that ordinarily used, and is much more durable.

So far as the writer can see, the only objections capable of being urged are that the head-gear is a little heavier than the common type, and that it may somewhat obscure the horse's upward vision, but neither of these has been found to be a disadvantage.

The extreme simplicity of this arrangement has caused the writer to hesitate before bringing it before an institution of engineers, but the dictates of humanity induce him to submit it, in the interests of a large class of colliery servants, who labour hard and regularly, are too often overworked and underfed, and who receive sometimes too little kindness and consideration. In the second place, the capital invested in pit horses is very large, and the loss of an eye is a serious pecuniary matter.

Mr. G. J. BINNS concluded by saying that he was unaware whether any similar head-stall had been used, but so far as he was concerned the idea was original.

Mr. SOUTHERN—Are the eye-covers difficult to make ?

Mr. BINNS—No, they are simply pump-bucket leathers.

The PRESIDENT, in thanking Mr. Binns for his paper, remarked that they all knew from practical experience the narrow and confined roads those ponies had to work in, and any protection they could give them in the shape of harness it was their bounden duty to supply. He was sure they were all indebted to Mr. Binns for his ideas.

Mr. BINNS, in replying, humorously remarked that anyone who had studied the evolution of the unidactyle *Equus* from its first ancestor the five-toed *Eohippus* must have been seized with a desire to breed for pit work a horse with a recessed eye, but he was afraid the time at their disposal would probably hardly allow of this, and under these circumstances his suggestion seemed to be one way of getting out of the difficulty.

DISCUSSION ON MR. F. S. MARSH'S PAPER, "ONE USE FOR THE TELEPHONE."*

The PRESIDENT remarked that the next paper was on the use of telephones in mines. They all knew the sad cause why the author of that paper was not present, and he had no doubt Mr. Stokes, who had seen the telephones in operation in one of the late Mr. Marsh's collieries would give them some information on the subject.

* *Trans. Fed. Inst.*, vol. iii., page 1007.

Mr. STOKES remarked they were all deeply sorry for the cause from which Mr. Marsh was not present. He was a rising young man and one in whom he took great interest. He (Mr. Stokes) once had to rely upon him in a very difficult and dangerous matter, in which he might have lost his life, but he bravely volunteered for the work. He was now dead, and it was only right to bear testimony to his work. As regarded the paper before them he did not know whether it would be quite in order, but if it were permissible he would ask the members to pass a vote of condolence, and also to express their appreciation of the paper, and let both resolutions be conveyed to his widow.

Mr. STOKES said he would endeavour to tell them what had passed between Mr. Marsh and himself on the subject of this paper. He had electric wires for signalling in his pit. He was arranging in each district, and also in each division of the mine, to fix a small wooden box, inside which he was going to put a telephone encased in a tin box—the object of the latter being to protect the telephone from injury and moisture. The telephones would be placed in various parts of the pit, and could be connected with the signalling-wires by means of short wires. The electric wires went to the surface, and in case he did not want to go down the pit he could go to the engine-house and communicate below by means of these wires with any particular deputy, in fact hold conversation with his officials in various parts of the mine, to give instructions to or receive messages from them, without leaving their districts. By this means also the deputies could be kept up to the mark, for they never knew when they would be wanted at the telephone. Another advantage was that, supposing the men were short of tubs in a particular roadway or working, they could speak to the man at the pit bottom or *vice versa*. Another advantage was that if they got a man injured, a message was immediately spoken to the surface, the ambulance was ready and the doctor sent for, and probably both were at the pit mouth before the man had arrived at the top. If they wanted to speak to anyone they had only to call by name and speak to him. Mr. Marsh told him that it was better to have three wires. If they had only two wires the signalling was stopped while they were speaking, but with three wires the signalling could go on without any interference. Both signalling and telephoning could go on at the same time. He thought that the introduction of telephones into mines, where they had wires used for electric signalling, was well worth serious consideration.

The PRESIDENT was sure, from these few remarks, they would be all convinced that if they could get better communication with their

distant underground stations it would be a benefit to all concerned. They had long roads at Annesley, one something like 5 miles long, and it was very difficult to know sometimes in which particular road an accident had occurred. It took some minutes to find it out.

Mr. STOKES said he had been a colliery manager himself, and knew that colliery managers liked to know the economical side of any innovation. Messrs. Davis & Son told him that the instruments cost only 10s. 6d. each.

Mr. J. B. SMITH asked how the instrument was connected to the wires?

Mr. STOKES said two short wires came from the telephone, each had a little hook, and they hooked the telephone wire to the signal wires. They could have the connecting-wires of any length.

Mr. SMITH said his wires were very far apart, one being on the other side of the roadway.

Mr. SOUTHERN—If that be so, he must have another wire?

Mr. STOKES—Yes. He begged to be allowed to propose the vote of thanks and condolence.

Mr. J. B. SMITH seconded the same.

The PRESIDENT said Mr. Marsh was very highly respected. He was a promising engineer, and it was a great pity they had been deprived of him. The Secretary would communicate the vote to his widow.

The following paper by Mr. W. S. Gresley on the "Geological History of the Rawdon and the Boothorpe Faults, in the Leicestershire Coal-field" was taken as read:—

GEOLOGICAL HISTORY OF THE RAWDON AND THE BOOTHORPE FAULTS IN THE LEICESTERSHIRE COAL-FIELD.

By W. S. GRESLEY.

For the sake of clearness, the subject is treated under the following heads:—

(*a*) Object in preparing the paper.
(*b*) Geological facts, furnishing a key to the solution of a problem.
(*c*) Rawdon or Moira Main fault.
(*d*) Boothorpe fault.
(*e*) Faulting in opencast clay workings of the Woodville district.
(*f*) Sequence of geological events arrived at from study of the phenomena.
(*g*) Value of observing and recording geological facts in mining operations.

(*a*) Although the writer is not now a member of this Institution, he ventures to think the facts and views recorded and expressed in this communication may be deemed of sufficient interest or importance to become the property of it, through the courtesy of the Secretary, who will probably introduce the matter. The paper is descriptive of phenomena in the district comprised by this Institution, and therefore more properly should belong to it than to any other, provided it be one coming within the scope of its objects.

(*b*) Among many other notes and illustrations of the local geology of the Moira, Gresley, and Swadlincote-Woodville districts of the Leicestershire and South Derbyshire coal-field, made between 1869 and 1889, which the author took with him to the United States, are those which furnish the subject-matter of this paper, so that the paper is not made from memory.

(*c*) It was in 1870, when the Moira Colliery company was winning the Main Coal on the downthrow side (east side) of the Rawdon or Moira Main fault,* that a carefully measured and levelled section was made by the writer of what was actually cut or driven through in a trial heading

* The throw at this point was about 351 feet, line or strike of fault being N.N.W. and S.S.E.

at about 1,040 feet from the surface, and about 600 feet from the bottom of the then recently widened and deepened Rawdon pit of the above company (see Fig. 1, Plate XX.). Now, this heading revealed two rather remarkable features: first, the extraordinary width or thickness of the fault material, *e f*, comprised between the two slips *s s'*, the hanging-wall and foot-wall as metal miners would call them. This thickness was 38 feet, measured horizontally; *i.e.*, a space of 38 feet separated the broken-off edges of the measures on the upthrow side (west) from those of the opposite or downthrow side. Within this space had accumulated an almost compact or solid mass of Coal-measures *débris*, consisting principally of binds, fireclays, sandstones, shales, and crushed pieces of coal, etc., with a good deal of pyrites (in crystals) and cementing material of lime and silica; and secondly, the presence, right in the body of this conglomeration of rock-fragments, etc., of what looked like a regular seam of coal, standing nearly on end (see *x*, Fig. 1, Plate XX.). This measured about 3 feet thick. Of course the position of this coal forbade its being a seam, or even a vein; it must have been nothing more nor less than a large mass, or "horse," as the lead miners would say, of one of the upper seams, of probably the west side measures, that had fallen from above, or had been dragged down, during the formation of this great dislocation of the coal-field, and which had become embedded, lodged, or caught up, engulfed and squeezed in the general brecciated mass at a period or stage of the world's history. The heading pierced this mass of coal, and no subsequent operations disclosed any of its edges. The heading itself has long since been abandoned, and walled or gobbed up.

The squeezed and faulted Main Coal in proximity to this fault should also be noted. At this point the Main Coal was found in an unusually hard and dense condition for many yards against the fault. This fault was crossed at about the same period at two other points, and at different elevations from Fig. 1, and exhibited the same general characteristics, but the writer does not recollect that anything like a seam of coal was met with in either case.

(*d*) *Boothorpe Fault.*—In 1879, the Midland Railway Company, in excavating the cutting of their Swadlincote and Woodville extension, at about 200 feet west of the tunnel under Woodville village, and, say 360 feet east of the girder bridge near the Albion Brick and Pipe Works, cut right through, square across, this large fault. This cutting exhibited an excellent and most interesting section; it showed on the east side, the Rafferee coal-seam *r* (Fig. 2, Plate XX.), dipping sharply against and cut-

off by the fault in question; and on the opposite side, faulted Permian and Triassic strata *p*, underlain by highly-disturbed Coal-measures, which crop out a little farther west close to the Pipe Works and the girder bridge. This point is about 1½ miles in a N.N.E. direction from the Rawdon section (Fig. 1). The throw of the fault in Fig. 2 is probably about 1,000 feet, because the Rafferee coal, being probably the same as the Stockings, is here on about the same horizon as the fireclays and marls which occur about 840 feet above the Main Coal.

Now the peculiarity about this Boothorpe fault near the surface in this cutting is its great width or thickness, viz., 12 feet, and the occurrence in it of lumps of coal (see *g* to *f*, Fig. 2, Plate XX.). Most of the matrix of this fault-material was dark-blue and blackish stiff clay, doubtless originally fragments of bind, etc., now softened by surface-water and weathering into a clayey mass. The writer would also point out that the great width and character of this mass at the surface shows that denudation must have removed an original upward extension of it to an unknown distance. The fault being vertical struck the writer as being unusual for the district. A reference to the 1 inch Geological survey map will show that this line of fracture and displacement extends for many miles in a S.S.E. direction, and for some distance to the N.N.W. It is a fault, the actual hitting or meeting of which is seldom done in mining operations, not because the coal-seams do not actually touch it, but because the strata flanking it are so disturbed by minor faults and thinnings, etc., of the seams as to make the working of them impracticable.

(*e*) *The Opencast Clay Workings, etc., in the vicinity of the Boothorpe Fault.*—As already mentioned, the well-known fireclay series of this district extend for some distance along the downthrow side of this fault. They come in below *p* in Fig. 2 and crop out towards the west, the north and the south, at distances varying according to local dip, topography, and other minor faults by which the coal-field is very much broken up.

The opencast clay-workings are very numerous, and thus have afforded unusually good opportunities for studying the thickness and character of the strata laid bare so often and in such a variety of ways (directions as to dip and so forth) over extensive areas at different depths, etc. The closer these clay excavations get to the Boothorpe fault the more numerous and more complicated are the small or local faults met with; reverse or overlap faults are not uncommon, and a strange variety of squeezes, nips, rolls, slides, slickensides, etc., have been observed, closely examined, measured, and sketched. The writer does not recollect ever seeing any disturbances such as these in any excavation on the east or

upthrow side of the Boothorpe fault in the district, but mining and open-cast workings are few in number on that side.

(*f*) Thinking over these local phenomena, as to why they should be there, what produced them, and when were they formed, etc., the writer came to the conclusion that in Figs. 1 and 2 he had the key to the answer to the problems. In explaining his theory he would state the order of events in which they seem to have happened in bringing about the results of to-day:—

Fig. 1.—Disclosed at 1,040 feet deep in 1870 (Rawdon fault).

„ 2.—Disclosed at surface in 1879 (Boothorpe fault).

„ 2.—Disclosed near surface, 1870-1889 (local clay-holes, faults, etc.)

„ 3.—Restoration of the original level or nearly level Coal-measures at the end of the Coal Period.

„ 4.—What happened at close of Coal Period—the surface A D was upheaved and rent open along the line *e f* (afterwards to become the Rawdon fault); the side A B being elevated far more than the side C D. The open gash or gulf *e f* became filled in with *débris* of the falling sides mixed with water, and possibly steam, perhaps bringing up mineral matters from below. The mass of coal *x* (Fig. 1), no doubt fell from above with the rest. Thus (if he was correct) the Rawdon fault was originally an upthrow to the east.

„ 5.—The overhanging enormous wedge-shaped mass of strata *e f g* (probably several cubic miles in size) broke away from A B along the line *f g*, and settling down into the chasm, took up the new position *e′ g′ f′*. Thus was the Boothorpe fault produced, and the Main Coal in the trough, brought below its former horizon, making the Rawdon fault have a downthrow to the east.

„ 6.—Shows how the upper strata of A and D (Fig. 4), and the still further broken strata in Fig. 5, have been planed down by general and long-continued denudation; how the gravels, marls, and sands of the Permian epoch then overspread the district, and how by this time the vertical open fissure *f g* of the Boothorpe fault, as well as that of its Rawdon neighbour on the west, had become filled up and consolidated.

„ 7.*—Another great change had taken place. A re-elevation of A B (Fig. 4) bringing the Rafferee coal nearly to the

* Figs. 3 to 7 are not drawn to scale, they are merely diagrammatic.

surface east of p', and carrying the Main Coal, etc., away up (see dotted lines), to be carried off by denudation, which also removed most of the overlying Permian beds, even of the west side. The effect of the upthrust of this huge body of rocks on the left (the east side), in his opinion, produced the side thrust which formed the many overlaps and singular freaks referred to under division *e*, and more clearly indicated in Fig. 2. The enormous squeeze to which these several blocks of Coal-measures have evidently been subjected, probably, at one period or another, he should say, certainly at several different periods during geologic times, will readily account for the many changes of dip, the innumerable lesser as well as the more serious faults of the district.

One other little feature in Fig. 7 is the occurrence at *e* of what is an outlier of Upper Coal-measures. As this overlies the Rawdon fault, where otherwise it would be at the surface, they had proof that the Upper Coal Series was deposited after the great faults were there, and after very widespread denudation had taken place.

(*g*) Thus he accounted for the (1) unusual width of the faults at Rawdon pit and Woodville cutting; (2) the brecciated constitution of the material of the former; (3) the verticality of the latter; and (4) the very faulted and tilted condition of the fireclay measures and their associated beds of coal, etc., in the Swadlincote and Woodville areas. At all events, the observed facts seemed to him to warrant the conclusion at which he had arrived; in other words the theory that the Rawdon fault is older than the Boothorpe, that the former was first an upthrow to the east and then converted into a downthrow; that the mass of Coal-measures forming the Rawdon-Woodville trough originally fell away from the main mass of the east side into the gap or abyss created to receive it. The diagram (Fig. 4) appears to suit the conditions they found. If any one could improve upon the theory he held, he was sure they should all be glad to hear it, as well as to be put in possession of any new facts tending to elucidate the subject.

He would just like to add, that whether he was correct or not, whether the time spent on such investigations as these was really worth anything —if it had not been for the notes, etc., he happened to take when the opportunity for getting the necessary data presented itself, this communication could not have been written. He thought it showed the real value of close observation and illustrated note-taking on the spot, for one never

knew but that such things (however trivial they may seem at the time) might some day come in most usefully. To all younger members, and especially those who spend much time underground, he strongly recommended the practice and habit of narrowly examining all faults and recording everything worth committing to paper.

He had devoted a good deal of time to the study of faults, and certainly his interest in this connexion had been more than ever aroused since he became acquainted with some of the coal-seams and their surroundings in North America, where a different set of phenomena are presented for study from those found in most of the British coal-fields. But still it seemed to him that, all points considered, no more fruitful field for observation and study in the fault-department could be found than that of Ashby-de-la-Zouch; for within it he had, at one place or another, observed instances of almost every kind of fault known.

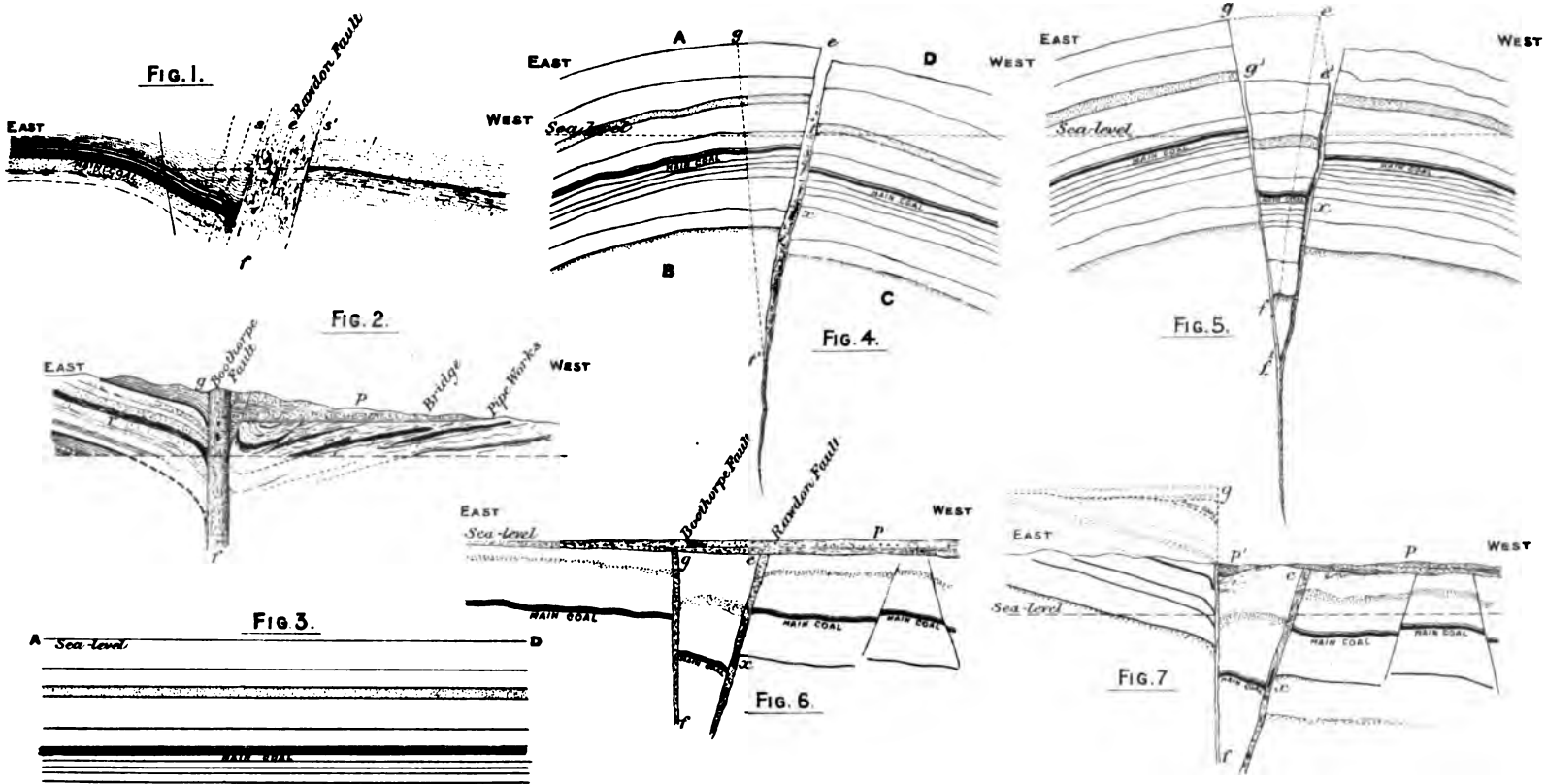
A few practical points brought out by the study of the sections disclosed, may not be altogether out of place here:—

1. The Rawdon fault (Fig. 1) shows the seams rising towards a downthrow, and dipping to an upthrow.
2. The Boothorpe fault (Fig. 2) is an instance of just the contrary, the strata there dip to a downthrow and rise against the upthrow.
3. That both the above effects should be attributed to side pressure or horizontal thrust, more than to upheaval or depression.
4. That the great thickness or width of the Rawdon fault, viz., 38 feet, could not be merely the result of its two slips or walls rubbing together, for it is evidently a filled-in deposit, a kind of huge dirt-vein occupying a once-open fissure between two vertically-displaced walls of rock.
5. The hade of the Boothorpe fault being *nil* at the surface is probably due to the eastern mass of strata having been pushed bodily over towards the west during its movement upwards; thereby compelling the beds on the west side to over-ride one another and become plicated as seen in Fig. 2.
6. That most, if not all, true faults are originally due to elevation.
7. That the Coal-measures were faulted at at least two different periods, viz., pre-Permian and post-Permian (see Figs. 6 and 7).

On the motion of Mr. J. B. Smith, seconded by Mr. H. R. Hewitt, a vote of thanks was passed to the Chairman, and the meeting broke up.

Federated Institution of Mining Engineers.
Transactions 1892-93

To illustrate Mr. W. S. Gresley's Paper on "The Geological History of the 'Rawdon' and the 'Boothorpe' Faults in the Leicestershire Coal-fields."



Scale of Figs. 1 & 2, 150 Feet to 1 Inch

Chesterfield and Midland Counties Institution of Engineers.
Transactions 1892 93

And^w Reid Sons & Co Lithos Newcastle

FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MUNICIPAL TECHNICAL COLLEGE, SCHOOL OF ART, DERBY, FEBRUARY 22ND, 1893.

MR. GEORGE LEWIS, PRESIDENT, IN THE CHAIR.

The PRESIDENT said it was a very great honour and privilege to have the pleasure of welcoming the Federated Institution of Mining Engineers on their first visit to Derby, and as the time came round again for further visits he could only say they would always be very welcome in the Midlands.

INTERNATIONAL CONGRESS OF ENGINEERS, CHICAGO, 1893.

The SECRETARY read the following letters :—

ROOM 902, THE TEMPLE,
CHICAGO, ILLINOIS, NOVEMBER 1ST, 1892.

TO THE PRESIDENT AND SECRETARY OF
THE FEDERATED INSTITUTION OF MINING ENGINEERS.

GENTLEMEN,—Under the auspices of the World's Columbian Exposition, and conducted by the "World's Congress Auxiliary," there is to be held in this city, in 1893, a series of International Congresses, among which there will be an International Congress of Engineers

This Congress will have its sessions during the week beginning Monday, July 31st, and ending Saturday, August 5th, 1893.

The Programme is given in the enclosed circular, to which your attention is specially directed for more detailed information.

We desire to cordially invite you, and through you, the members of your Society, to participate in this Congress.

Desiring an acceptance of this invitation at an early day, and hoping that many of your members will find it convenient to attend.

We are, very respectfully,
GENERAL COMMITTEE ON ENGINEERS' CONGRESS,
WORLD'S CONGRESS AUXILIARY,
BY E. L. CORTHELL, CHAIRMAN.

GENERAL PROGRAMME.

GENERAL ORGANIZATION.—The affairs of the Engineering Congress are intrusted to a general committee, assisted by an Advisory Council, appointed by the Honorable Charles C. Bonney, President of the Congress Auxiliary.

The General Committee will have direct control of the organization and proceedings of the general sessions of the congress. It will determine the general programme of proceedings and the times and places of the divisional sessions. It will, unless otherwise found necessary hereafter, issue the programmes and public announcements for all sessions.

All formal invitations to participate in the congress will be issued by the General Committee. In order that a complete list thereof may be in its possession, the representatives of the several divisions will transmit to the General Committee from time to time the names of such additional persons or societies as they may desire to have invited, and such persons or societies will be at once formally invited. Such invitations will entitle the recipients to free participation in the proceedings of all sessions without assignment or special relation, however, to any one division.

In order to prevent any possible misunderstanding through accident or clerical error, it is hereby announced that all individuals or delegates who have been invited by the representative of any division, but, for any reason, have not received the official invitation of the General Committee, will be entitled to receive such invitation at any time.

Communications upon subjects in direct charge of the General Committee, should be addressed to Mr. E. L. Corthell, Chairman, Room 902, "The Temple," Chicago.

The congress is to comprise seven divisions, as follows:—

DIVISION A.—Civil Engineering, in charge of the American Society of Civil Engineers. Address F. Collingwood, Secretary, 127 East Twenty-third Street, New York, N.Y.

DIVISION B.—Mechanical Engineering, in charge of the American Institute of Mechanical Engineers. Address F. R. Hutton, Secretary, 12, West Thirty-first Street, New York, N.Y.

DIVISION C.—Mining Engineering, in charge of the American Institute of Mining Engineers. Address R. W. Raymond, Secretary, 13, Burling Slip, New York, N.Y.

DIVISION D.—Metallurgical Engineering, in charge of the American Institute of Mining Engineers. Address R. W. Raymond, Secretary, 13, Burling Slip, New York, N.Y.

DIVISION E.—Engineering Education, in charge of a special committee appointed by President Bonney. Address Prof. I. O. Baker, Chairman, University of Illinois, Champaign, Ill.

DIVISION F.—Military Engineering, in charge of Major Clifton Comly, U.S.A., representing the United States War Department at the Columbian Exposition. Address Major Clifton Comly, Governor's Island, New York Harbor, N.Y.

DIVISION G.—Marine and Naval Engineering, in charge of Commodore George W. Melville, Engineer in Chief United States Navy. Address Commodore George W. Melville, Engineer in Chief, U.S.N., Washington, D.C.

The divisional sessions will be organized and controlled by the officers in charge of the divisions. There may be joint sessions of two or more divisions, which will be similarly controlled by the divisions concerned.

Correspondence concerning the papers and proceedings of any division should be addressed to the representative thereof, and not to the General Committee.

TIME AND PLACE.—The time assigned to the Engineering Congress is the week beginning Monday, July 31st, and ending Saturday, August 5th, 1893.

There will be an opening general session at 10 o'clock on Monday, July 31st, 1893, in one of the large halls of the Art Palace now building in the Lake Front Park in Chicago. This is in the business or down-town part of the city and not at the Exposition grounds. After appropriate addresses the divisions will be convened in their respective session rooms in the same building.

CARDS OF ADMISSION.—Cards of admission to the Engineering Congress will be issued by the Secretary of the General Committee, upon the presentation of introductory cards given by the officers in charge of the several divisions, or by the officers of the societies invited to participate in the congress.

The cards of admission will entitle the holder to attend the meetings of any of the sessions. There will be no entrance fee for participation in the proceedings.

PROCEEDINGS.—The proceedings will consist of the reading and discussion of such papers as shall have been accepted by the management of each division and according to the rules which may be adopted. It is expected that a number of these papers will be secured and printed early in 1893 so that copies can be obtained (but not for publication) by those desiring to offer contributions to the discussions.

In general the papers will not be read at length in the congress, but will be printed in advance and presented in brief abstract, so that the discussion may proceed with as little loss of time as possible. As a general rule, precedence will be given to those who shall have sent in discussions in writing, and subsequently to those who shall have given notice of their desire to be heard.

Papers to be presented will, for the most part, be secured by direct invitation, but offers of papers are welcome at any time, subject, however, to acceptance by the officers in charge of the division to which such papers may belong.

Preference will be given to papers which relate to new and important constructions, machines, processes, methods, experiments, and investigations. It is very desirable that papers be sent in early, and this may be essential for securing their favorable consideration.

Correspondence relative to the time when proposed papers must be transmitted for acceptance should be addressed to the representative of the divisions concerned.

Opportunities will be given for the display of wall diagrams and of stereopticon (magic lantern) views in illustration of papers.

It is intended that all papers printed by the divisions shall be in English. Papers may be offered in French, Spanish, German, and other languages, and, if accepted, will be translated and printed in English. Discussions may be in any one of the three languages mentioned, and interpreters will be provided whenever necessary. It is evident that contributions requiring translation should be transmitted at the earliest possible day. Information concerning scale, size of drawings, etc., should be obtained from the representatives of the divisions, who will also issue advance copies of the papers.

A daily programme will be issued each morning by the General Committee stating the order of papers and proceedings, so that engineers in attendance may select the sessions at which they prefer to be present. This programme will indicate the rules to be followed, and as far as practicable, the speakers who are to take part in the discussions.

There will be five morning sessions of the divisions, some of which may be joint sessions.

The congress will terminate with a general morning session on Saturday, August 5, 1893, on which day there will be no divisional sessions.

The afternoons may be devoted to further sittings, or to visits to the Exposition or other points of engineering interest, as may be determined by the divisions.

It is expected that the evenings will be given up to receptions and social intercourse.

PUBLICATIONS.—It is contemplated to publish the entire proceedings of the Engineering Congress and to sell copies at cost to engineers who may subscribe for the same, but the societies having in charge the management of divisions will have the right of publishing appropriate portions of the proceedings of their divisions. All contributions accepted will be subject to the usual control of these societies over their own publications, including the editing of manuscripts, the determination of typographical style, and the number, scale and kind of engravings, the concurrence of the author being secured on all essential points, and proofs being submitted to him when time permits. This will not interfere with any publication for which the Auxiliary may arrange.

Correspondence on this subject should be addressed to the divisions.

EXCURSIONS AND TRANSPORTATION.—After the close of the Engineering Congress, it is intended to arrange for excursions to points of engineering interest, particulars of which will be announced later.

Arrangements are now in progress for securing the lowest practicable rates of transportation for those attending the congress.

LONDON, W.C., JANUARY 28TH, 1893.

TO THE SECRETARY OF THE
FEDERATED INSTITUTION OF MINING ENGINEERS.

MY DEAR SIR,—On behalf of the Committee of the International Engineering Congress to be held during the week ending 5th August next, at Chicago, I venture to ask you to submit this letter at an early date to your Council. My hope in making this request is that your Council may see fit to consider the best means of bringing the subject under the notice of the members of your Institution, with a view to assisting towards the success of the Congress, and to give facilities to such of your members as may desire to assist at the Congress, either by their presence or by contributing papers for reading and discussion.

I would also especially wish to bring before the consideration of your Council the question as to the possibility of having your Institution officially represented at the Congress, either by your Secretary or by some member of your Council. Such a courtesy on the part of your Institution would most certainly be deeply appreciated by the engineers of the United States, and especially by the Committee of the International Congress.

As Honorary President of the Congress I hold myself entirely at the disposal of your Council and the members of your Institution, and I shall take the liberty of again communicating with you on this subject as soon as I receive detailed information about the Congress from Chicago.

Yours faithfully,
JAMES DREDGE.

Prof. CLOWES read the following paper on "A Portable Safety-lamp with Ordinary Oil Illuminating Flame, and Standard Hydrogen-flame for Accurate and Delicate Gas-testing":—

A PORTABLE SAFETY-LAMP WITH ORDINARY OIL ILLUMINATING FLAME, AND STANDARD HYDROGEN-FLAME FOR ACCURATE AND DELICATE GAS-TESTING.

By Professor FRANK CLOWES, D.Sc., Lond.

Introductory.

In a previous paper communicated to the Federated Institution of Mining Engineers on May 28th, 1891,* a description was given of the test-chamber devised for the examination of safety-lamps. It was not intended to test the safety of the various forms of lamps, but to ascertain the relative delicacy and accuracy of the lamps when applied to the detection and estimation of fire-damp.

The Test-chamber.

The test-chamber, as then described (Fig. 1), has been improved in several respects. It is now furnished with a top aperture, which corresponds in size to the lower aperture through which the lamps are introduced (see Figs. 2 and 3). Both of these openings are closed by water-seals. The lower water-tray is now slung in a frame suspended by four pivotted rods from the bottom of the chamber. It is thus easily moved away, and brought again into position, without any adjustment or disturbance of its horizontal position. The opening of the top and bottom of the chamber, for two minutes after a lamp-test is completed, allows the chamber to become filled entirely with fresh air; and the process

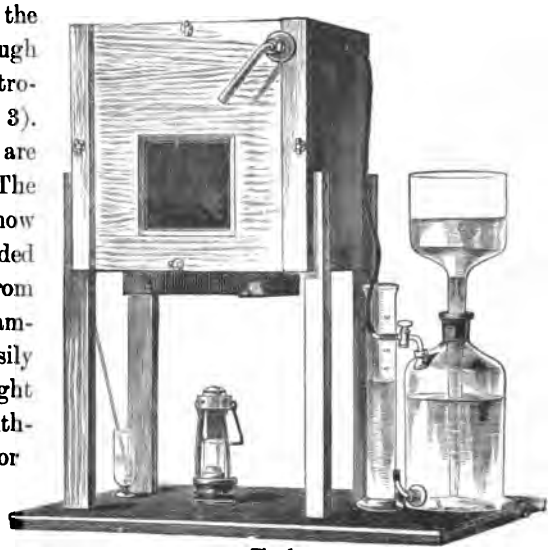


Fig. 1.

* *Trans. Fed. Inst.*, vol. ii., page 355.

can be hastened by swinging the internal flap. The flap is now cut away at one side, sufficiently to allow of a safety-lamp standing in the chamber while the flap is being swung to obtain a mixture of gas and air; the lamp can therefore be placed in position, before the chamber is finally closed for the introduction and mixture of the gas. It was found that the lower opening in the chamber might remain unclosed for at least five minutes without affecting the flame-cap indications. A further improvement consists in the introduction of a small circular opening in the bottom of the chamber immediately beneath the position in which the lamp stands. This opening enables the pricker of the lamp to be reached from outside while the test is proceeding; the wick of the lamp can thus be conveniently adjusted after the introduction of the lamp into the chamber. This aperture is closed when necessary by a suitable hinged

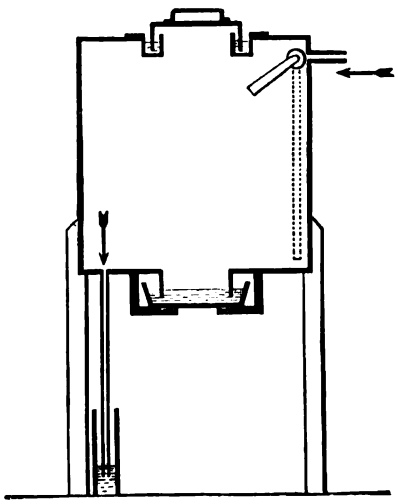


Fig. 2.—Section.

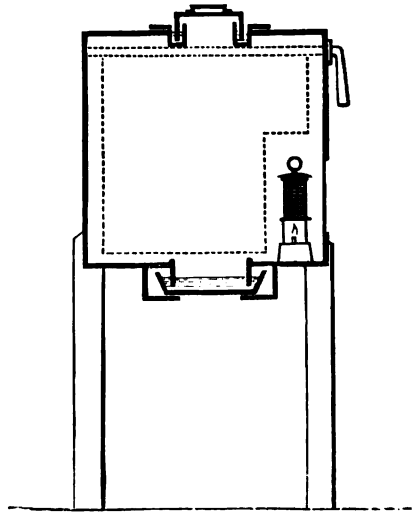


Fig. 3.—Side Section.

flap, which may be quickly clamped air-tight. A large internal hinged flap also closes the lower large opening when soluble gases or vapours are present, and prevents them from being absorbed by the water in the water-seal.

The chamber is made to contain precisely 100 litres of air. Accordingly the percentages of gas are readily measured off without calculation.

The test-chamber has been now employed for a very considerable number of observations. It has been found exceedingly easy, rapid, and convenient in use; and its application is already extended to several

centres for the purpose of quickly showing those who are concerned in gas-testing, or in testing for inflammable vapours, precisely what they must expect to see when using a testing-lamp.

Comparative Examination of Lamps.

In testing the merits of existing safety-lamps as gas-detectors, those only were selected to compare with the ordinary flat oil-flame, which were professedly delicate and accurate. Accordingly, the examination has thus far included the following :—

O, the oil-flame furnished by a flat wick fed by a mixture in equal measures of colza and petroleum (water-white) in the Ashworth modified detector lamp.

B, the benzoline-flame in the same lamp with round wick.

H, the flame of hydrogen suitably introduced into the same lamp.

P, the alcohol-flame of the ordinary Pieler lamp.

The caps were measured over these flames by means of a flat parallel rule, prepared with luminous paint, so as to be visible in the dark room in which the experiments were made. The rule was pressed in a horizontal position flat against the window in front of the chamber, with a vertical strip of paper supported between it and the glass. The rule was then opened until it exactly included the height of the flame-cap, and this space was marked with a sharp pencil upon the paper strip. The height thus marked was read off on a millimetre-scale, and corrected for the distance between the rule and the lamp. Successive uncorrected readings rarely differed by as much as one millimetre.

In every case the cap was observed against a dead-black non-reflecting surface, which was produced by smoking a narrow strip on the interior of the back of the lamp-glass. This was found to be by far the most suitable means of rendering pale caps visible.

The oil-flame was adjusted in two ways. It was first drawn down gradually until its light was just sufficiently reduced to make the cap visible and of maximum size (O_1). The flame was then drawn down until all luminosity was destroyed (O), and the cap was again observed.

The benzoline-flame (B) was drawn down until its luminous tip just disappeared, leaving a pure blue flame.

The hydrogen-flame was usually adjusted by a standard wire inside the lamp, to exactly 10 millimetres (0·39 inch) in height (H). But for very low percentages the flame was raised to 15 millimetres (0·59 inch) in height (H_1), and for high percentages the flame was reduced in the presence of the gas to 5 millimetres (0·20 inch) in height (H_2).

The alcohol-flame of the Pieler lamp was set to the one standard height (P), indicated by the conical shield, viz., 30 millimetres (1·18 inches).

Some uncertainty was introduced into the lowest readings obtained by the oil-flame, and the benzoline-flame, by the fact that a pale mantle was visible over these flames in air free from gas. This mantle increased in density but not in size, when small quantities of gas were present in the air. Even a practised eye found some difficulty in distinguishing, with certainty, between this mantle and the cap. The Pieler alcohol-flame showed a slender thread of flame-mantle in gas-free air; this was, however, distinguishable with care from a feeble cap. The hydrogen-flame of the dimensions used in testing showed no mantle in gas-free air, which could be mistaken even for a faint cap; this was one distinct advantage secured by using this flame for testing.

Comparative Heights of Flame-caps Observed over the Different Lamp-flames.

The following tabular statement gives the mean results obtained by a number of cap-measurements made in the manner described above. The heights and breadths of the flames used are also stated; these dimensions are given in millimetres, and when multiplied by 0·0394 will give the equivalents in inches.

Percentage of Fire-damp.	Flat Oil-flame, 13 mm. broad at base.		Round Benzoline-flame in Ashworth Lamp. 7 mm. broad at base; height about 3 mm.	Round Hydrogen-flame.			Round Pieler Alcohol-flame. 13 mm. broad at base; 30 mm. height.
	Blue Flame. Height about 3 mm. O	Maximum Flame. Height about 6 mm. O_1	B	5 mm. broad in middle; 10 mm. standard height. H	6 mm. broad in middle; 15 mm. height. H_1	5 mm. broad in middle; 5 mm. height. H_2	P.
0·25	Nil.	Nil.	Nil.	*17	37	Nil.	†[30]
0·5	"	"	†[7]	18	42	"	65
1·0	"	"	10	22	60	"	90
2·0	*7·5	*7·5	14	31	Reaches glass top.	"	Reaches lamp top.
3·0	7·5	7·5	20	52	...	14·5	...
4·0	12	24	25	Reaches glass top.	...	22·2	...
5·0	29	41	30	...	...	35	...
6·0	67	Reaches glass top.	35	...	...	60	...

* Cap more pale and hazy in outline than in next higher percentage.

† Cap indication somewhat uncertain, since the cap was not higher than the flame-mantle.

The flame-cap heights contained in the above tabular summary are represented in Figs. 4, 5, 6, 7, and 8, while Fig. 9 shows the actual size of the different test flames used. In Fig. 4 the dotted lines represent the caps over the maximum oil-flame (O_1). Fig. 6 gives the drawing to actual height of the hydrogen-flames and flame-caps, but the enlargement in breadth of the hydrogen-flame and cap is not shown; neither is the creeping downwards of the cap towards the base of the flame with the higher percentages of gas indicated.

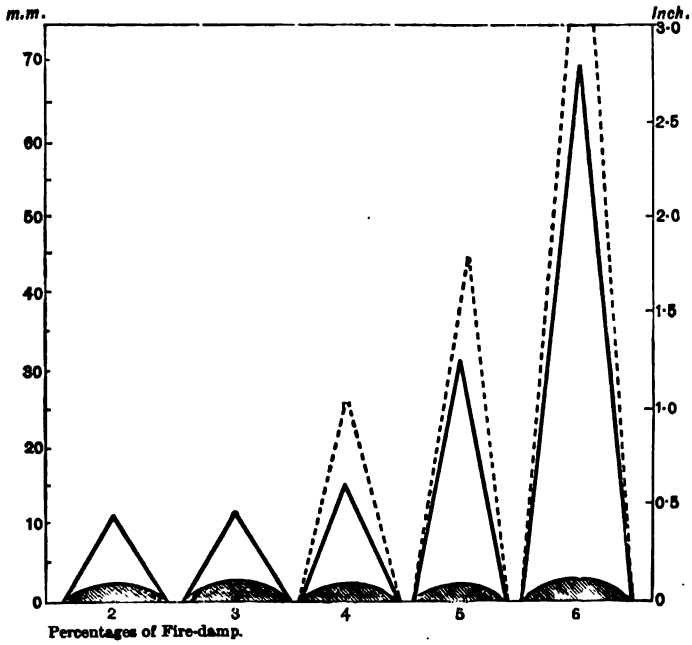


Fig. 4.—Oil-flame (Colza-petroleum) and caps (full size).

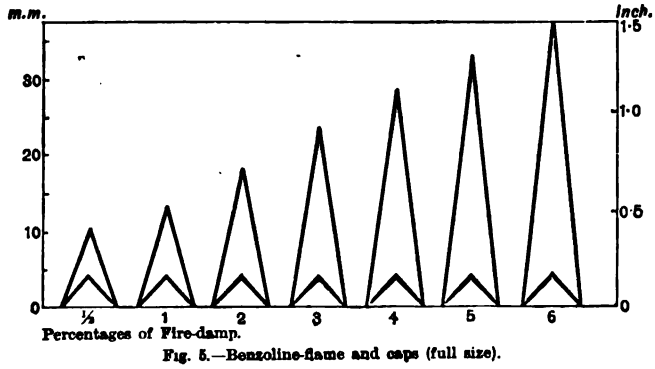


Fig. 5.—Benzoline-flame and caps (full size).

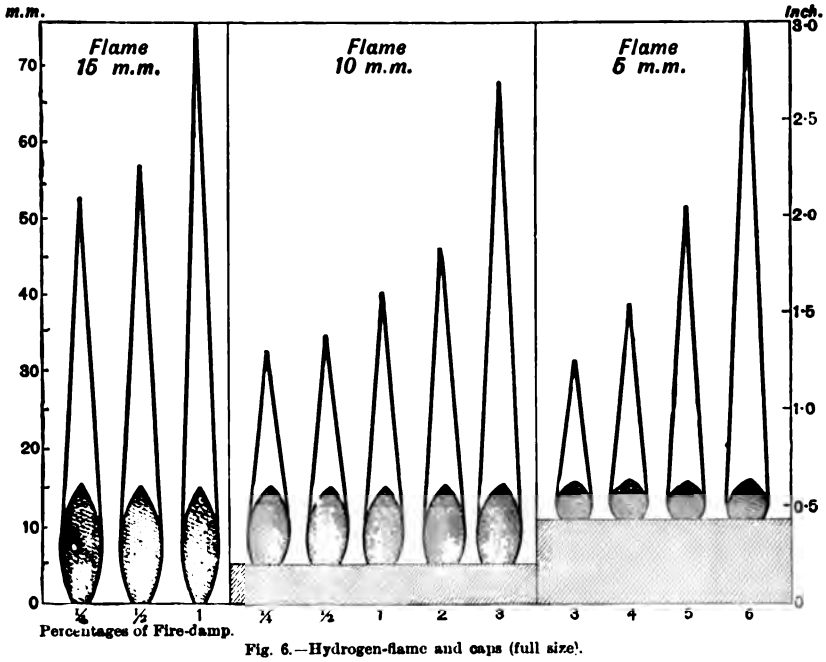


Fig. 6.—Hydrogen-flame and caps (full size).

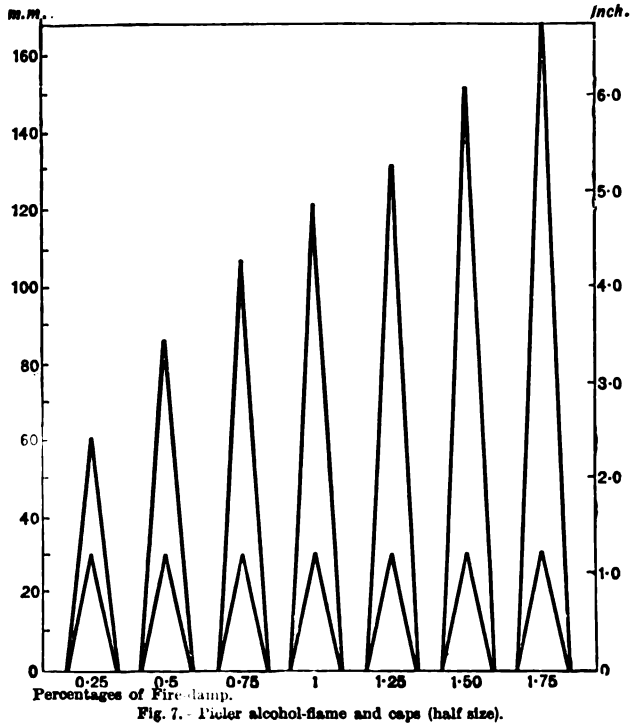


Fig. 7.—Fidler alcohol-flame and caps (half size).

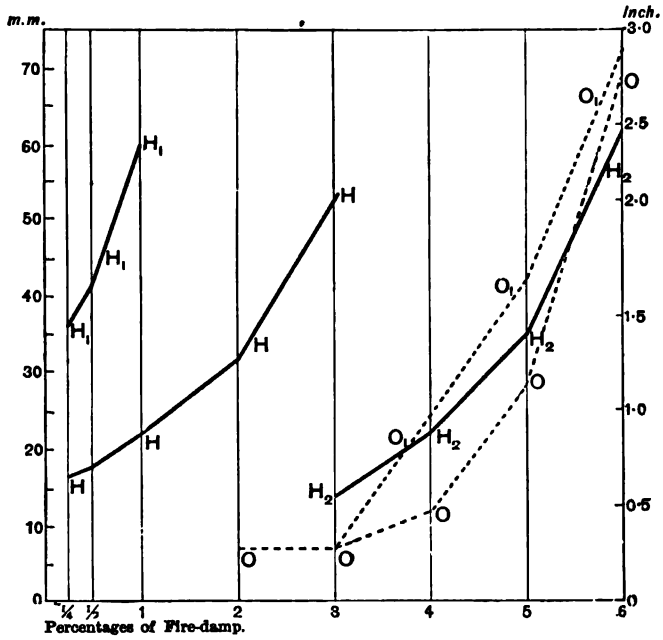


Fig. 8.—Heights of caps (full size).

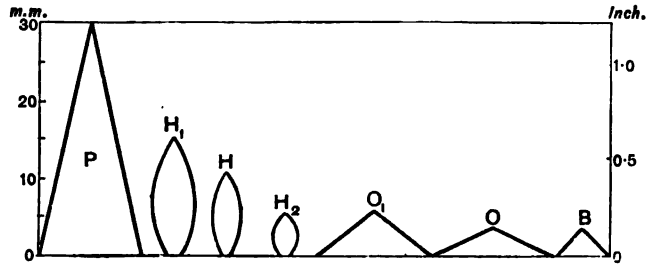


Fig. 9.—Testing-flames (full size).

Conclusions Drawn from the Experimental Results.

The following conclusions may be drawn from the measurements obtained in the test-chamber:—

1. That under the favourable conditions employed, the oil-flame of the safety-lamp does not indicate any proportion of gas in the air below 2 per cent.
2. That for percentages of gas in the air varying between 3 and 6, the oil-flame gives distinct indications.

   Experience shows, however, that these indications are not concordant, since it is impossible for many reasons to produce the test-flame always of standard size and nature;

and when the reduced flame is obtained it is constantly falling in size, and is very liable to be extinguished.

3. The benzoline flame gives very regular and satisfactory indications for percentages of gas varying between 1 and 6. Its indication for 0·5 per cent. is somewhat doubtful.

The reduced benzoline-flame is less liable to extinction than the oil-flame, and is much more easily obtained in a pale and standard condition.

4. The hydrogen-flame gives exact indications for percentages of gas varying from 0·2 to 6, that is through the whole range usually tested for.

The height of the flame may be varied for the different percentages, being set to 15, 10, or 5 millimetres (0·59, 0·39, or 0·20 inch) according as the percentage of gas is very low, medium, or high.

This adjustment of the flame can be effected with absolute precision and with great rapidity.

The standard flame is always producible at once, and maintains itself unchanged.

The hydrogen-flames used in testing are so pale that they require no screening from the eye, and they in no way interfere with the perception of the cap. At the same time they burn so vigorously, that they are practically inextinguishable by the movement of the lamp or of the surrounding air.

The standard 10 millimetres (0·39 inch) hydrogen-flame may be used for the measurement of gas from 0·25 to 3 per cent. These indications may then be supplemented by the indications of the oil-flame, instead of employing the reduced hydrogen-flame.

Hydrogen gas is more easily obtained of constant composition than is any other fuel burnt in safety-lamps. This makes the flame less variable.

5. The Pieler alcohol-flame measures percentages of gas varying from somewhat less than 0·25 to about 2. It therefore requires supplementing by another lamp.

Experiments made with this lamp showed that the lowest indications were made somewhat uncertain by the presence of a tall pale mantle over the flame in gas-free air. Also that all the caps were rendered indistinct by the necessity of examining them through gauze instead of

through glass, and of observing them against an unsuitable background.

Further, the flame was constantly varying in size and adjustment, and the lamp in its ordinary form is by no means free from danger.

The Pieler lamp suffers under the further serious disadvantage of being non-luminous; it must therefore be carried together with an ordinary oil-lamp, which serves for lighting purposes and for testing for percentages of gas from 2 upwards.

The general conclusion arrived at from the series of experiments was that a hydrogen-flame was far more suitable for detecting and measuring gas than were the flames of oil, benzoline, or alcohol, and attempts were made to apply the hydrogen-flame in a safe and suitable way.

Methods of Applying the Hydrogen-flame to the Detection and Measurement of Fire-damp.

The superiority of the hydrogen-flame over all other flames for gas-testing purposes was acknowledged in France by Messrs. Mallard and Le Chatelier, in 1881 (*Annales des Mines*, series 7, vol. xix., page 186), and in Prussia, in 1883, by Mr. Fr. Pieler. Occasional reference has been made to the desirability of applying the flame to this purpose by other writers. But hitherto all attempts to introduce the use of the flame have failed, since the generator recommended for stationary test-apparatus was very inconvenient, and the adaptation of hydrogen to a portable safety-lamp has been found impracticable.

In 1892, the writer* published the satisfactory results obtained by applying hydrogen, derived from a store compressed in a steel-cylinder, to an ordinary safety-lamp.

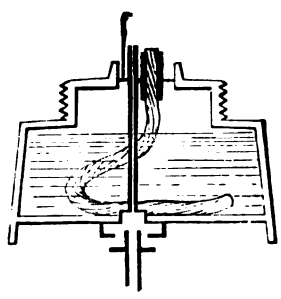


Fig. 10.

The gas was led by a flexible rubber or metal tube to a nozzle. The nozzle was readily connected at the bottom of the lamp (Fig. 10) with a fine solid-drawn copper tube, which terminated in a jet close to and just above the lamp-wick. When the lamp was burning and closed, the hydrogen could thus be introduced into the lamp and at once lighted by the oil-flame. The wick was then drawn down until the oil-flame was extinguished, and the hydrogen-flame was set to standard size against a fixed wire near the jet, by regulating the valve of the hydrogen-

* *Proc. Royal Society*, vol. li., page 90.

cylinder. This hydrogen-flame was employed for testing, and when it was no longer required it served to light the wick when this was pushed up. The hydrogen was then turned off and the connecting-tube withdrawn. In this way an ordinary safety-lamp could be supplied with a standard hydrogen-flame when necessary, and the same lamp could be used either with an oil-flame or hydrogen-flame as might be necessary, the change from the one flame to the other being made without opening the lamp or losing the flame inside it.

At first, large steel cylinders containing 40 cubic feet of hydrogen were employed, and since these were not portable, the apparatus was necessarily a stationary one. Then small steel cylinders, containing about 4 cubic feet of hydrogen and weighing about 4 lbs., were carried slung from the shoulder, and thus the apparatus was made portable. This store of gas furnished a standard hydrogen-flame, burning continuously for about 16 hours. The store of gas thus employed was unnecessarily large for a single testing of an ordinary coal-mine; and it was next attempted to reduce the size and weight of the gas-cylinder to such an extent as to make it attachable directly to the safety-lamp.

This has now been successfully accomplished, and the writer acknowledges with pleasure the very considerable advantage gained by the co-operation, at this stage of his work, of Mr. J. M. C. Paton of the firm of Messrs. Manlove & Alliott of Nottingham. Fig. 11 represents the Ashworth modified testing-lamp with such an attached cylinder. Fig. 12 shows the lamp with the hydrogen-cylinder detached; and Fig. 13 is a section of the lamp. The cylinder weighs a little more than 1 lb. It can be attached to the lamp above and below instantaneously by a quarter-turn, and it then forms a convenient rigid handle at the side of the lamp. The gas-connexion with the lamp is at the side, and a small detachable key serves to regulate the gas. The smallest cylinder is 5 inches in length by 1 inch in diameter; and several such cylinders can be easily carried together in the pocket; or a longer cylinder extending from top to bottom of the lamp may be used if more gas is required. The cylinder is rapidly and simply attachable to a large store-cylinder of compressed hydrogen for taking its charge. If stored under a pressure of 100 atmospheres, the smallest cylinder will feed the standard hydrogen-flame continuously for more than 30 minutes; the larger cylinder gives over 50 minutes supply. A single hydrogen test, passing from the oil-flame back to the oil-flame, can be made in 30 seconds; and since the hydrogen-flame would commonly be used for detecting low percentages of gas only, which the reduced oil-flame had previously failed to indicate, the supply of hydrogen furnished by one

cylinder would serve for more than one complete inspection of the mine. If the additional weight of the cylinder on the lamp is objected to when the lamp is carried for some distance, the cylinder may be carried in the pocket, and only be attached when it is required.

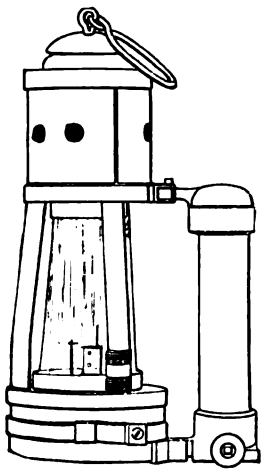


Fig. 11.

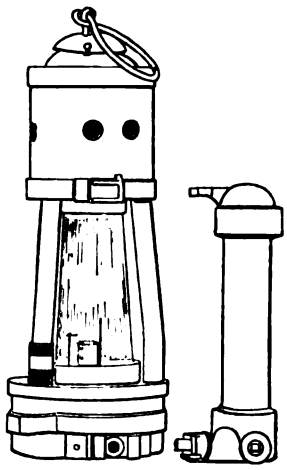


Fig. 12.

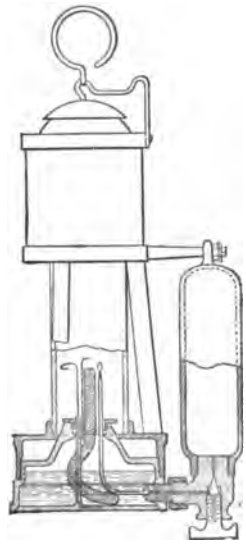


Fig. 13.

The miner is thus furnished with an illuminating lamp and with an extremely delicate gas-testing and gas-measuring lamp in one. He can make his somewhat rough tests for the higher percentages of gas near the working-face with the reduced oil-flame in the ordinary way ; and he can at any moment change his lamp into a most delicate and accurate gas-indicator, by simply attaching the hydrogen supply and working with the hydrogen-flame instead of with the oil-flame. He would naturally apply the delicate testing to the constant examination of the returns, or to looking for traces of gas in a dusty mine before firing a shot. In these cases less than 1 per cent. of gas has to be detected and estimated, a feat which no ordinary oil-lamp can accomplish.

It should be noted that the hydrogen-flame can be set to its standard height in the presence of the gas in measuring the flame-caps, and that the test can, therefore, be at once made in the air to be examined without previously placing the lamp in gas-free air.

The portable hydrogen-lamp dispenses with the necessity of using a stationary lamp, fed from a larger reservoir of the gas. But this may occasionally be found advantageous, and a separate apparatus has been devised for bringing up samples of the air from the mine and testing them at a stationary hydrogen-flame above ground.

Influence of the Ventilation-current and of Coal-dust on Gas-testing.

It has been suggested by several practical men that the indications furnished by the test-lamp in the still air of the test-chamber would undergo considerable modification when the lamp was exposed to the ventilation-current of the mine. That this would be the case seemed to be highly improbable, provided only that the safety-lamp used was one whose flame was not affected by the motion of the air; and this is now considered to be a condition of safety in any lamp. The Ashworth modified oil-lamp was acknowledged to be unaffected by even high-speed ventilation-currents. It was only reasonable to infer that its flame-caps would be equally unaffected by the air-current.

This was tested by enclosing the lamp in a 12 feet wooden gallery. The lamp stood near one end of the gallery, and could be observed through a glass window; this end of the gallery could be closed by a large flap when necessary. The gallery being open, air was blown down from the further end by a high-speed fan, driven by an electric motor. The speed of the current passing through the tube was 300 feet per minute. Coal-gas was admitted with air at the intake end, and the hydrogen-flame in the lamp indicated 0·5 per cent. of gas. The fan was then stopped, and at the same moment the flap was closed: the lamp was thus exposed to a mixture of gas and air of the same composition as before, but at rest instead of in rapid motion. The indication of the lamp was absolutely unchanged.

The same result was obtained on experimenting in a similar way with an oil-flame in the lamp, but using a higher percentage of gas.

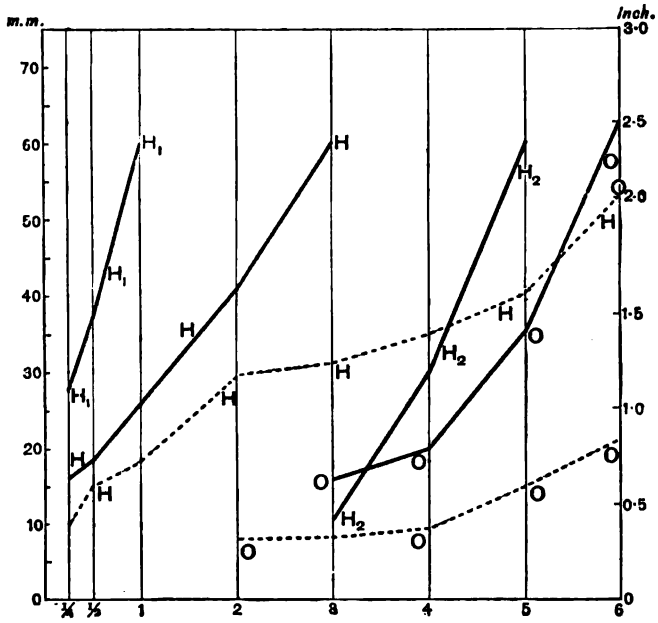
It may therefore be concluded that the results yielded in the test-chamber are applicable to the mine, provided only that a suitable and really safe form of lamp is employed.

The presence of a very large quantity of fine coal-dust in the air has been found, however, to cause serious interference with all flame-tests. The flame becomes so luminous with heated particles that the pale cap is invisible. This difficulty only arises in extremely dusty air, and is not experienced ordinarily.

Application of the Hydrogen Safety-lamp to the Detection and Measurement of Coal-gas and of Water-gas in the Air.

The new hydrogen and illuminating safety-lamp may be employed for lighting and for testing in air containing coal-gas. The measurement of its cap-indications in the test-chamber show that they are somewhat greater for coal-gas than for the corresponding percentages of fire-damp in air.

The indications for water-gas can be carried as low as 0·25 per cent., but they increase very slowly as the percentage of water-gas rises.



Percentages of Coal-gas (continuous lines) and of Water-gas (dotted lines).

Fig. 14.—Height of caps (full size).

The following are the tabulated cap-heights stated in millimetres, which are converted into inches by being multiplied by 0.0394 :—

Percentage of Inflammable Gas in the Air.	Coal-gas.				Water-gas.			
	Hydrogen-flame.			Oil-flame. Maximum Height. O_1	Hydrogen-flame.			Oil-flame Maximum. O_1
	10 mm. H	15 mm. H_1	5 mm. H_2		10 mm. H	15 mm. H_1	5 mm. H_2	
0·25	15·7	27·6	Nil	Nil.	10	25·3	Nil.	Nil.
0·5	18·4	37	"	"	14·5	33	"	"
1·0	25·3	*60	"	"	17·2	...	"	"
2·0	40·6	...	"	"	28·7	...	"	8
3·0	60·0	...	11·5	15·3	31·4	...	"	8
4·0	Top of lamp glass	...	30	20	*36	...	"	9
5·0	...	...	60	34·5	*40	...	11	14·5
6·0	...	...	Top of lamp glass	60	*50·6	...	26	20

* Measured without including the slender tail above the cap.

The above results are shown in a diagram to actual size in Fig. 14.

Detection and Measurement of Benzoline-vapour in air by the Hydrogen-oil Safety-lamp.

The new safety-lamp may be applied for safety purposes to lighting spaces which may contain petroleum-vapour. Such spaces occur in petroleum tanks and stores, and in rooms in which light petroleum oil is employed for any purpose. If the lamp is fitted with the hydrogen testing-apparatus, it becomes at the same time a delicate indicator of the petroleum-vapour, as is shown by the following results of flame-cap measurements.

Air charged with benzoline-vapour by slowly bubbling through a tall column of liquid benzoline was introduced by the lower opening into the test-chamber. Since this air was much heavier than atmospheric air, it displaced air from the upper part of the test-chamber. Each mixture was tested in a separate vessel to ascertain its behaviour with a naked flame. The non-inflammable mixtures were then examined in the test-chamber with the hydrogen-flame. The results are stated below :—

Proportion of Benzolized air to air in the Mixture.	Behaviour of the Mixture with a Naked Flame.	Height of the Cap over the Hydrogen Safety-lamp Flame in the Mixture.
1 : 4	Violently explosive.	
1 : 5	Burns rapidly, and would probably be explosive if fired in large quantity.	
1 : 6		
1 : 7		
1 : 8	Burns around a flame only.	
1 : 9	Non-inflammable.	
1 : 23	"	52 mm.
1 : 36	"	43 " (4 " over benzoline-flame.)
1 : 72	"	31 "
1 : 144	"	22 "

The results of these experiments showed that the 10 millimetres hydrogen-flame in the Ashworth safety-lamp will detect a quantity of benzoline-vapour in air which is only $\frac{1}{36}$th that of the explosive proportion, and $\frac{1}{20}$th of that which is inflammable when mixed with air. The benzoline-flame in the Ashworth lamp shows a very small but distinct cap when the amount of benzoline-vapour is $\frac{1}{9}$th that requisite for the production of an explosive mixture, and $\frac{1}{5}$th that which will yield an inflammable mixture.

It would appear from this that the new lamp will be of great service in indicating danger arising from petroleum vapour, and special apparatus for collecting and testing air containing the vapour is now in course of construction.

Mr. A. SOPWITH (Cannock) asked, with regard to the darkening or smoking of the glass by means of a wax taper, whether it was not almost as valuable as the introduction of the delicate flame? He thought that Messrs. Mallard and Le Chatelier found that by darkening the glass behind the flame they could ascertain the presence of $\frac{1}{4}$ per cent. of gas. If the simple darkening of the glass enabled them to ascertain the presence of so small a percentage of gas, they need not make use of the hydrogen-flame. He asked Prof. Clowes if he thought that percentage of gas would be observed without the introduction of the delicate hydrogen-flame? He also asked whether any attempt had been made to introduce this new method of testing into electric lamps, so that they might have a gas indicator combined with an electric lamp?

Prof. LUPTON (Leeds) observed that he had had the opportunity of examining one of these lamps. He saw $\frac{1}{2}$ per cent. of gas very clearly, and he was delighted with the apparatus. He had been asked what was the use of these delicate tests? It was their business to collect information, and knowledge was certain to be of some use. These delicate tests would enable them to measure the percentage of gas existing in the return airways. In conclusion, he would like to know how Prof. Clowes produced the rapid currents of air and gas in which he made some of his tests?

Mr. W. COCHRANE (Newcastle-upon-Tyne) asked whether there was a scale attached to the lamp, so that the observer could distinctly say there was $\frac{1}{4}$ per cent., $\frac{1}{2}$ per cent., or more or less of gas in the air, and whether the mixture in the tests was sufficiently representative of the mixtures found in a mine?

Mr. T. A. SOUTHERN (Derby) said the last speaker had brought forward an important question. Prof. Clowes said that the table* was the result of a large number of experiments. If in those experiments there was great variety and great range in the readings, then any single test in the mine might give them very unreliable information. It seemed, even if not valuable for everyday use by deputies in examining the returns, that the lamp would be probably very valuable for occasional tests by colliery managers to ascertain the state of the return airways in the various districts of the mine as regarded the presence of gas.

Mr. D. A. LOUIS (London) remarked that there were two or three points in this lamp which appeared to suggest inconveniences, more especially as regarded its behaviour in explosive mixtures. One was the use of a very small flame inside the lamp for testing purposes; now the

* *Trans. Fed. Inst.*, vol. iv., page 444.

great sharpness and distinctness of the caps produced in this lamp would most probably lead to its adoption, whatever conditions prevailed, in preference to the ordinary and much less satisfactory oil-flame; and Mr. Marsaut had demonstrated and maintained that little flames like that were far more dangerous, in the presence of gas, than larger flames. Another point was the length and shape of the glass; such glasses had been found to be considerably more dangerous than short glasses, owing to the greater resistance offered in the case of internal explosion in the lamp. He thought, therefore, that the combination of the very long glass of conical shape, and the very small testing flame, might render the use of the lamp even somewhat dangerous under certain circumstances. Then, again, considering that mines are not the cleanest of places, and a miner's pocket scarcely a suitable receptacle for unprotected delicate apparatus, it seemed highly probable that the small apertures in the nozzle and in the socket, through which the hydrogen had to pass to gain access to the inside of the lamp, would very soon get wholly or partially choked with dust and give rise to unpremeditated developments, which might interfere with the progress of the testing.

Mr. Walton Brown (Newcastle-upon-Tyne) said he had not had the advantage of using the new lamp, but he had been in the habit of using the Pieler lamp, and it was a matter of opinion whether the use of the Pieler lamp and the ordinary lamp was not as simple as this lamp with its attachments. He deprecated the use of either lamp in the probable presence of gas exceeding 2 per cent., as the Pieler lamp then became rapidly heated, and there was the great danger of the gauze being burnt or of the flame passing through it. For less than 2 per cent. of gas, the Pieler lamp gave better results and would be easier to use than the hydrogen-flame lamp. The results obtained by Prof. Clowes with the Pieler lamp differed from those usually accepted; but taking his figures, the comparative heights of the caps with less than 2 per cent. of gas, were:—

Percentage of Fire-damp.		Round Hydrogen-flame H.			Round Pieler Alcohol-flame P.	
		Millimetres.	Inches.		Millimetres.	Inches.
¼	...	17	·67	...	30	1·18
½	...	18	·71	...	65	2·56
1	...	22	·87	...	90	3·54
2	...	122	1·22	...	140	5·51

It would take very careful observation to detect and measure the difference between ·67 and ·71 inch, representing ¼ and ½ per cent. of gas respectively, in the hydrogen-flame lamp; and Prof. Clowes stated that successive readings had differed by more than this difference. With the Pieler

lamp, there was a most marked difference in the heights of the cap, which rendered the lamp most suitable for use in making tests in mixtures containing less than 2 per cent. of gas. If any one was careless of his life, tests could be made with the Pieler lamp, in mixtures containing higher percentages of gas, with as great accuracy as the hydrogen lamp. The round glass was also objectionable, as it would tend to obscure the caps on the hydrogen-flame. There was a very important fact to be borne in mind, viz., the difficulty and almost impossibility of testing for gas in the presence of coal-dust.

Mr. H. DAVIS (Derby) asked if the attachments were not applicable to any other than the Hepplewhite-Gray safety-lamp?

Prof. CLOWES, in reply to the remarks, said Messrs. Mallard and Le Chatelier did not introduce a black film upon the lamp-glass. They preferred to use a black cloth, which had an admirable surface, and they also used curved screens which shielded the light of the reduced flame from the eye; by these means the presence of $\frac{1}{4}$ per cent. of gas could be detected; the indication, however, was extremely slight, and it was very difficult to see it at all. There was no difficulty in seeing $\frac{1}{4}$ per cent. in the lamp he had described, or in the Pieler lamp. The great objection to the Pieler lamp was that they had to look through the gauze, which deadened the light; the cap was seen more readily in his lamp although it was smaller. He thought the hydrogen-flame could be easily adapted to the electric-lamp; and it could be kindled with the electric spark. He held a strong opinion as to the value of such delicate tests, and several of the mining engineers and managers he had met during the last few months had acknowledged their importance. It would not be necessary to test each of the working-places, but a test in each of the returns would probably be accepted as sufficient evidence of the state of the entire mine. The experiments with rapid air-currents were made in a long wooden tube, into which the lamp was introduced, and a small fan driven by an electric motor produced an air-current moving at a velocity of between 300 and 400 feet per minute. He had tried to arrange for the use of a scale of inches in the hydrogen lamp. Unless it was placed very close to the flame its use had the disadvantage that a vertical shift of the lamp caused a perceptibly different reading. It was much more important to have an accurate reading with the hydrogen lamp than in the Pieler lamp since its caps were smaller. He had left the method of estimating the cap height an open question. A man who was used to judging $\frac{1}{2}$ or $\frac{3}{4}$ inch could estimate the heights of the cap with precision. In practice no difficulty was felt in distinguishing the caps yielded by $\frac{1}{4}$ and by $\frac{1}{2}$ per

cent. of gas, although their heights were nearly equal. The cap was pale and very hazy with ¼ per cent. of fire-damp, while that for ½ per cent. was much more substantial and sharp. The fire-damp used in his experiments was chemically prepared, and corresponded very fairly with the fire-damp of a mine. The measurements of the caps were the averages of a large number of tests, and hence it might be thought that the readings of the individual results differed very widely; the difference never exceeded 1 millimetre, and it was only to secure great accuracy that he was led to repeat them. The experiments were repeated time after time, so as to be quite sure that the results recorded with the same percentage were always the same. Mr. Louis had referred to the danger of using a small flame, and to the danger arising from a long funnel-shaped glass. The lamp had been tried, however, with oil and hydrogen-flames in the test apparatus, and the worst result was extinction. They had never had the slightest explosion or continuous burning inside the lamp. In using the lamp in the mine, there had never been obstructions in the little openings. Mr. Walton Brown suggested that the lamp ought not to be exposed to a high percentage of gas as the gauze would be injured, and had compared the hydrogen-flame with the Pieler-flame rather unjustly. The hydrogen lamp had been tried in high velocities and high percentages of gas with perfectly satisfactory results, and it would behave itself better than expected. He had been asked why hydrogen and alcohol-flames gave larger caps than oil and benzoline-flames. He thought it was because those flames were so pale that they might be made large and hot, without interfering with the perception of the pale cap. With oil and benzoline the flames used were necessarily small, else they became luminous, and in consequence they could not yield long caps. With alcohol they could not increase the flame much, as it became bright and interfered with their testing. With hydrogen they could increase it to any extent, as it did not become bright, and it gave correspondingly larger caps. In his opinion the apparatus could be applied to any form of safety-lamp. He had applied it to the Ashworth-Hepplewhite Grey safety-lamp, as he believed it was the best gas-testing-lamp. He had experienced the difficulty mentioned by Mr. Walton Brown, of being unable to ascertain the presence of small percentages of gas in the presence of large amounts of coal-dust; and recently in mentioning this difficulty to a gentleman who had had some experience in collieries, he at once suggested filtering the air, and he intended to try it. There was a chamber in the lamp into which cotton-wool could be introduced. They could fill this with cottonwool, the air could be thus filtered from coal-dust, and the lamp used for gas-testing

in the presence of coal-dust. They could not ascertain the presence of 1 per cent. of gas in the presence of much coal-dust, unless they adopted some system of filtration as suggested. No estimations had been attempted above 6 per cent., as he did not consider higher measurements to be necessary.

Mr. G. C. GREENWELL (Duffield), in proposing a vote of thanks to Prof. Clowes for the interesting and important paper he had given them, could not sit down without remarking that engineers experienced in the working of fiery mines must know perfectly well that at all times, especially in the working of tender coal, the air was more or less loaded with fine coal-dust, and that at no time in the day were they free from the possibility of the atmosphere being charged with gas. This often came suddenly, and he was afraid that this lamp would not then be useful for the purpose for which it was required. Prof. Clowes had mentioned that the condition of the main return of a mine was an index to the whole of the atmosphere throughout that mine. No colliery viewer would say, when the main return was fairly free from gas, or which possibly contained less than 1 per cent. of gas, that the whole of the mine was safe. The air of the main return was derived from the different splits into which the fresh air was divided. One of these splits might be in an absolutely dangerous state, but the main return would not necessarily be so. If the returns from each district came separately into the shaft, and they tested each of these returns, then they might gauge the general condition of the mine by them. He could himself cordially thank Prof. Clowes, and he hoped they would, by acclamation, award him a hearty vote of thanks.

Mr. W. F. CLARK (Birmingham) had great pleasure in seconding the vote proposed by Mr. Greenwell. They all wanted some instrument of a reliable nature to detect gas in a mine. Prof. Clowes had given a great deal of labour, time, and thought to the matter, and the very least they could do was to accord him a hearty vote of thanks.

The vote of thanks was agreed to unanimously.

Prof. CLOWES after acknowledging the vote of thanks, explained that in suggesting that the returns should be tested for gas, he meant that after they had tested the main return, they should proceed to test the returns from each of the working districts. They would not consider the testing complete until both the main return and the district returns had been examined.

Mr. SOUTHERN read the following paper on "The Estimation of the Actual Effective Pressure or Water-gauge in the Ventilation of Mines":—

THE ESTIMATION OF THE ACTUAL EFFECTIVE PRESSURE OR WATER-GAUGE IN THE VENTILATION OF MINES.

By T. A. SOUTHERN.

In introducing this subject to the notice of members and asking their attention to some remarks thereon, the writer will enunciate three propositions which he believes are extensively accepted and relied upon by mining engineers and others, in connexion with calculations relating to the ventilation of mines:—

I.—That, where a fan is used for ventilation, the water-gauge, taken on the fan-drift, with one leg open to the fan-drift and the other to the outer air, shows the total ventilating-pressure; that is to say, the total difference of pressure which is producing the ventilation of the mine and keeping the air-currents in motion in opposition to the resistances offered by the surfaces of the airways.

II.—That the difference between the water-gauge at the fan-drift and the water-gauge on the separation-doors near the bottom of the shafts, shows the whole pressure which is being spent in overcoming shaft-friction; that is to say, the resistances met with by the air in passing through the downcast and upcast shafts.

III.—That, when a water-gauge is used to ascertain the difference of pressure between two given points, A and B, in the intake and return airways respectively, it shows the whole ventilating-pressure which is being spent in overcoming the friction of the air-currents in the passages beyond the points A and B, or in other words, on the in-bye side of these points.

The object of this paper is to assert most distinctly and emphatically that each of these suppositions is entirely erroneous, and that they are not merely erroneous as a matter of theory, but that reliance upon them has often led to very serious practical errors, involving great waste of capital, through miscalculations in the designing and construction of ventilating appliances.

In his apprenticeship days, the writer was always led to believe in the truth of the above propositions, and it may be admitted that at first sight

they appear consistent and worthy of belief. The second proposition is further supported by the fact that, at probably 99 collieries out of every 100 which are ventilated by fans, the water-gauge at the shaft bottom is somewhat less than the water-gauge on the fan-drift, and the difference between them is, in most cases, such a proportion of the fan-drift water-gauge as may reasonably be supposed to represent that portion of the ventilating-pressure which is being spent upon shaft friction.

From 1876 to 1883 the writer noticed several cases of fan ventilation and in all of them the water-gauges at bank and underground bore this relation to each other, the latter being less than the former; but in 1883 an instance came under his notice at Cwmaman colliery, near Aberdare, where the water-gauge on the underground doors was invariably greater than the water-gauge on the fan-drift. As this disagreed with his previously-acquired notions as to the amount and distribution of the ventilating-pressure in fan ventilation, the circumstance induced him to consider and investigate the subject in the hope of ascertaining the correct explanation, and he now proposes to state the conclusion at which he arrived.

At Cwmaman colliery, in 1885, the total quantity of air passing through the mine (measured in the downcast shaft) when the fan was running at 50 revolutions per minute* was 55,000 cubic feet per minute, the water-gauge on the fan-drift was 1·50 inches, and at the same time the water-gauge on the underground doors was 1·90 inches. The mean temperature of the air in the downcast shaft was 66 degs. Fahr., and in the upcast shaft 109 degs. Fahr., there being three underground high-pressure steam engines working, which exhausted into the upcast.

These figures are the averages of a long series of observations, any one set of which would show very similar proportions, and these observations, unlike observations made with the ultimate hope or object of showing the immense superiority of some particular type of fan, were made before the writer had formed any conclusions or even suppositions as to the real explanation of the underground water-gauge being higher than the fan-drift water-gauge. The writer therefore claims for these figures that they are free from the least suspicion of having been influenced, even by an unintentional bias, either one way or the other, when making the observations. The fan-drift water-gauge was read with a loose water-

* In regular work, the fan was run at a higher speed, with a larger quantity of air, but this speed was adopted as a convenient one to maintain throughout a number of experiments conducted under various conditions, some of them being of an exceptional character.

gauge, by simply thrusting its nozzle tightly into a hole bored in the inner door leading into the fan-drift. The readings from this water-gauge corresponded exactly with the water-gauge in the fan engine-house, attached to a pipe whose open end simply passed into the fan-drift some feet away from the inlet and was not in the path of the air-current. The underground water-gauge was also read with a loose gauge attached to the inner separation-door in a passage between the intake and return. This passage entered the return airway at right angles with the air-current, so that in this case also the water-gauge was not influenced by having the air-current blowing either across, along, or against it; but in order that no doubt whatever may be entertained on this point it may be mentioned that the readings of the underground water-gauge upon the separation-doors in two other passages between the intakes and returns from other districts were just a little less than 1·90 inches, and were not lower than 1·85 inches; and even this very slight difference was fully accounted for by the fact that these other separation-doors were a little farther from the shafts.

The mine was ventilated by means of one downcast shaft and one upcast shaft. The downcast shaft, elliptical in form, 15 feet by 9½ feet, was 232 yards deep; the upcast shaft, circular, 9½ feet in diameter, was 225 yards deep. It may also be mentioned, though it has no bearing whatever upon the relation existing between the surface and underground water-gauge to which attention is now specially directed, that the mine was then ventilated by a Guibal fan, 30 feet in diameter and 8 feet wide, and has now a largely-increased ventilation produced by a high-speed Waddle fan.

The writer's first experience with ventilation had been with furnace ventilation at a large mine, and he was therefore already aware of the fact that the ventilating-pressure produced by a furnace, cannot by any means, while the ventilation is passing, be all measured by a water-gauge, for the reason that part of it is used up in the very place where it is produced, viz., in the downcast and upcast shafts, being expended in overcoming the friction of the air in its passage through these shafts. He was also aware that the water-gauge observed on the separation-doors at the shaft bottom, as is usual in furnace ventilation, does not include this portion of the ventilating pressure, but could be made to include it, if it were necessary and practicable, by extending up the shafts a continuous open pipe which shall have in it a column of still air of the same density as the air in the shafts, and attaching a water-gauge to it in such a way that it will show the tendency of the column of air to pass through the pipe.

Reasoning from these facts, he calculated the water-gauge due to the difference of temperature in the two shafts in the case above cited, in the same way as would be done in furnace ventilation, as follows:—

Assuming the barometer to be 30 inches, at which pressure 459 cubic feet of air at 0 degs. Fahr. weigh 39·76 lbs.,

the weight of 1 cubic foot of air in the downcast $= \frac{39{\cdot}76}{459 + 66} = {\cdot}0757\dot{3}$ lb.

the weight of 1 cubic foot of air in the upcast $= \frac{39{\cdot}76}{459 + 109} = {\cdot}07000$ lb.

the difference of weight per cubic foot $= {\cdot}0057\dot{3}$ lb.

and this difference multiplied by the depth of the upcast shaft, 675 feet, gives 3·87 lbs. per square foot as the difference of pressure due to the difference of temperature in the two shafts. Then 3·87 lbs. ÷ 5·2 = 0·74 inch water-gauge.

It will probably be perfectly self-evident that this higher temperature of the upcast does actually add to the ventilating-pressure of the mine and assist the action of the fan. The fact may be seen still more clearly and convincingly by considering an exactly opposite case in which the air in the downcast shaft was heated by any means so as to take away its preponderance and render it lighter than the air in the upcast, for it will be apparent that in such a case the difference of temperature would act against the fan by producing an opposing water-gauge.

The fan-drift water-gauge of 1·50 inches represents a difference of pressure at the top of the shafts of 1½ inches of water column = 7·8 lbs. per square foot, due to the action of the fan, the less pressure being at the top of the upcast. The above calculation shows that the difference of temperature in the shafts is capable of producing a further difference of pressure of 0·74 inch water-gauge = 3·87 lbs. per square foot at the bottom of the shafts, the less pressure being here also at the upcast shaft. Hence, if none of this pressure was used-up in the shafts, or in other words, if it were possible for the air to move in the shafts without friction, the water-gauge at the bottom of the shafts would read 1·50 + 0·74 = 2·24 inches, that is to say, the diminution of pressure upon the upcast produced by the fan *plus* the further diminution of pressure at the bottom of the upcast, owing to its higher temperature.

As already stated, the actual reading of the water-gauge on the separation-doors at the shaft bottom was 1·90 inches, and the writer submits that the difference, 0·34 inch, between this and the above calculated water-gauge, is an exact measure of the amount of ventilating-pressure spent upon overcoming the friction of the air-currents in the shafts. He also submits

that the pressure actually spent in overcoming shaft friction may be ascertained in the same way for any ordinary case of fan ventilation.

In order to establish the practical importance of this matter he would endeavour to show, very briefly, that a very serious error may result from adopting an erroneous method of calculation.

Assuming that all the airways in this mine were practically level, then the water-gauge of 2·24 inches would be the total ventilating-pressure of this mine under the conditions cited; but, according to the first proposition stated at the commencement of this paper, the total water-gauge of this mine would be regarded as being 1·50 inches (that is to say, by simply taking the fan water-gauge), and the writer believes, as already stated, that this view, although erroneous, is often adopted in everyday practice, the influence of the difference of shaft temperatures being entirely ignored.

Let it be supposed that it has become necessary for the ventilation of this mine to be doubled, by applying a more powerful fan with precisely the same airways; and, as a fact, this very problem did present itself at about the time referred to in the history of this mine, the observations quoted having been made in connexion with this object. To obtain the double quantity of air four times the ventilating pressure is required, because the pressure to overcome friction varies in proportion to the square of the quantity. If it were assumed (according to the ordinary erroneous process) that the fan-drift water-gauge showed the total ventilating-pressure, it would then be said that the new fan must produce a water-gauge of $1·50 \times 4 = 6·00$ inches, and that if it gives this water-gauge it will give the double quantity of air. Disappointment would most certainly be the result, for the new fan, being calculated upon an incorrect basis, would not do what was expected of it. Disappointment in the results achieved by new fans has been an exceedingly common experience, notwithstanding that a long record of such disappointments has led mining engineers and inventors and makers of fans to provide large margins to cover the discrepancies of which even experts, with an extensive experience in connexion with fans, have not hitherto been able to understand the cause. The writer believes that in nearly every case the cause of such discrepancies will be found in the fact that the real water-gauge has not, in the first case, been properly ascertained.

In the case above described the real total water-gauge was 2·24 inches, and therefore to obtain the double quantity it would be necessary to have a water-gauge of $2·24 \times 4 = 8·96$ inches. A small portion of this water-gauge will still be produced by the difference of shaft temperature, but the water-gauge so produced will not be so much as before the

quantity was increased, because the temperature in the upcast shaft will be reduced by the increase of the volume of air passing through the mine, and there will not be an equal decrease of temperature in the downcast shaft. But even if the water-gauge due to the shaft temperatures was quite as much as before, the new fan would have to be capable of giving a water-gauge of 8·96 — 0·74 = 8·22 inches on the fan-drift, instead of the water-gauge of 6·00 inches indicated by incorrect reasoning.

Lest it be said that undue stress is being placed upon the influence of shaft temperatures, and that, although the effect is considerable in the particular case described, it is due to the use of steam underground, and that it will not be of equal importance in a mine where steam is not used underground, the writer wishes to forestall this objection by pointing out that the difference of temperature quoted, viz., 109 degs. — 66 degs. = 43 degs. Fahr., is such as may exist for several months of the year in any moderately deep and extensive mine, from purely natural causes and without the aid of exhaust steam; for example, it would occur with a temperature of: downcast shaft, 40 degs. and upcast shaft, 83 degs., or downcast shaft, 45 degs. and upcast shaft, 88 degs.

In the foregoing remarks the writer has assumed that the airways of this mine were level. This was necessary, in order to admit of his making use of the water-gauge of 2·24 inches as being the total ventilating-pressure of the mine, thus obviating further calculation.

If the difference of level between the shaft-bottom and the face of the workings of each district, or between the shaft-bottom and any intermediate point, is inconsiderable; in other words, if no portion of the airways is highly inclined, or, being slightly inclined, is not so for a considerable length, then, in such a case, the total water-gauge found by adding that due to shaft temperature to that due to the fan, may with sufficient accuracy for practical purposes, be regarded as representing the total effective ventilating-pressure of the mine. But in all other cases it becomes necessary to take into account the difference of temperature between the intake and return airways in precisely the same way as in the case of vertical shafts. The water-gauge due to such differences of temperature in inclined roadways being dependent simply upon the mean temperatures and the vertical differences of level, regardless of the lengths of the roads, and, the return air being the warmer, rise districts of workings will present an opposing water-gauge, which must be deducted in order to ascertain the effective water-gauge ventilating these districts; while dip districts will present an assisting water-gauge, which must be added in order to ascertain the effective water-gauge which is carrying on the ventilation of these districts.

The importance of this point may be shown by an illustration. Take the case of a pair of airways, intake and return, inclined at a gradient of 1 in 6 and extending 1 mile out from the shafts, and assume the mean temperature of the intake at 50 degs. and the return at 70 degs. Fahr. The vertical difference of level will be 5,280 ÷ 6 = 880 feet, and the water-gauge will be the same as would be due to the same temperature in vertical shafts of this depth.

Weight of 1 cubic foot of air in the intake airway $= \frac{39 \cdot 76}{459 + 50} = \cdot 0781$ lb.

Weight of 1 cubic foot of air in the return airway $= \frac{39 \cdot 76}{459 + 70} = \cdot 0751$ lb.

Difference of weight per cubic foot $= \cdot 003$ lb.

and this difference of weight, 0·003 × 880 feet = 2·64 lbs. pressure per square foot ÷ 5·2 = 0·50 inch of water-gauge. So that in this assumed case there is a further water-gauge of 0·50 inch to be added if it is a dip district, and to be deducted if it is a rise district, in order to find, in conjunction with the water-gauge due to the fan and shaft temperatures, the total water-gauge as regards this particular district. It may be remarked in passing that this also explains the fact that an increased speed of the fan ventilating an inclined seam does not of necessity produce an equal proportionate increase of ventilation in both the rise districts and the dip districts, but will, assuming the return air to be lighter than the intake, produce a larger proportionate increase of ventilation in the rise than in the dip districts. In dip districts a part of the effective water-gauge is due to difference of temperature, and any increase of the speed of the fan or power of the furnace increases only the other portion, and not the whole of the total effective water-gauge; and at the same time such increase by fan or furnace, by increasing the quantity of air passing, causes a reduction of the temperature in the return, and slightly reduces that portion of the effective water-gauge due to the difference of temperature. In rise districts all these conditions are reversed; for their effective water-gauge is the fan or furnace water-gauge *minus* the water-gauge due to the difference of temperature in the inclined airways: hence any increase of the fan or furnace water-gauge produces a corresponding increase in the whole of the effective water-gauge of the rise districts, and it also produces a further slight increase (because the increase of air causes a reduction of the temperature in the return airway, and thus reduces the water-gauge due to the difference of temperature, which, in rise districts, acts in opposition to the fan or furnace water-gauge).

By these last remarks it is shown that the third proposition stated at the outset of this paper is only true with reference to level airways, and also for inclined airways in which the temperature is the same in the intake as in the return. This proposition, in order to be accurate, should therefore have the following stipulation appended to it:—Provided that the whole of the airways beyond the said points A and B are level, or, if they are not level, then provided that the temperature is uniform throughout.

In stating that the ventilating-pressure produced by a furnace cannot all be measured by a water-gauge, the writer has limited this statement by the words "while the ventilation is passing" because he believes that the whole effective ventilating-pressure of any mine, whether ventilated by a furnace, or fan, or otherwise, can be most accurately ascertained by measurement with a water-gauge by arresting the whole air-current for a few moments by a door or doors across the airway or airways at any convenient point, and quickly reading a water-gauge, one leg of which has been passed through one of the temporary stoppings, so that the gauge shows the difference of pressure upon the opposite sides of the stopping. This process may be applied either to ascertain the effective water-gauge of the mine, considered as a whole, or, by placing the stoppings and reading the water-gauge on them in the airways of the various rise and dip districts, it may be utilized to ascertain the effective water-gauge of each district, and will thus serve to show by calculation what effect will be produced on the ventilation of each district by any definite change in the speed of the fan or extra firing of the furnace; or, on the other hand, what change in the latter will be required in order to produce a given change in the ventilation of a particular district.

In applying this method with furnace ventilation, it would obviously be necessary for the stoppage of the air-current to be of short duration, and therefore the reading of the water-gauge will of necessity be taken before the upcast had probably acquired a higher temperature than it had while the air was passing in it, hence it is not anticipated that error need occur from this cause. In a case of fan ventilation, provision must be made for keeping the fan at its normal speed, by reducing its supply of steam directly the air-current is stopped; for otherwise the fan, having no air passing through it, will at once run away and produce a much higher water-gauge.

The writer ventures to assert that by this method the actual effective water-gauge produced by all causes can be accurately determined, although he has had only one opportunity of proving it by experiment, viz., in a

case of fan ventilation aided by a difference of shaft temperature, and he does not suggest that this method is absolutely necessary, but that where practicable it is a convenient means of proving the accuracy of results arrived at by calculation. On the other hand, his contention is that the real total effective water-gauge can be calculated for any mine by the method named in this paper; but, as will be seen from what he has stated, in some mines working a number of separate districts in various directions in a steep seam, a number of observations of temperature and a number of separate calculations are required to ascertain accurately the effective ventilating-pressures existing in connexion with the different districts.

It is hoped that the foregoing remarks, having reference to a very important subject, will be found interesting and instructive, and that the statements made will commend themselves to the approval and acceptance of the members. The writer regrets that he has been obliged to confine this paper within narrower limits than was at first his intention, but he hopes to revert to the subject at an early date, and to offer some further remarks thereon for consideration at a future meeting.

Prof. LUPTON (Leeds) said with regard to the suggestion of testing the effective ventilating pressure of the furnace or fan by suddenly stopping the air-way for a few moments and taking the instantaneous reading of the water-gauge, in either case he supposed the water-gauge record would indicate the effect due to the temperature of the air or the speed of the fan, but he thought it would also indicate that there was, plus the effect of the momentum of the air-current against the temporary obstruction, the combined effect of the temperature of the shaft and the velocity of the current. Of course, as Mr. Southern pointed out, very few managers would be prepared to stop the air-current. Mr. Southern had advanced three propositions, and he believes that these are extensively accepted and relied upon by mining engineers and others in connexion with calculations relating to the ventilation of mines. With regard to "the others" he said nothing, but with regard to the mining engineers, he would be much obliged if Mr. Southern would chalk upon the board the names of mining engineers who accepted or inculcated the three propositions he disputed. No fault could be found with the calculations put forward by Mr. Southern as correct.

Mr. W. COCHRANE said he thought it was a wrong conclusion on the part of Mr. Southern, that it was general not to take account of every

element concerned in the formation of the air-current. Temperature might be such a large item that it could not be neglected. If they had a donkey and a horse pulling a cart, and they wanted four times the amount pulled they would not say they wanted four horses, and forget the four donkeys. They must not forget the donkeys in their calculations. Everything should be particularized in an existing ventilation in order to estimate the requirements of varying it. In summer or winter the temperature had different effects on the air going through the fan, and therefore he would advise that observations should be taken when the temperature was about the same in each shaft. In most mines the temperature added to the current did not require to be taken into consideration.

Mr. W. SPENCER (Leicester) remarked that at one time it was thought that the variations of the water-gauge were valuable as indicating the condition in the return airways. He had quite recently seen that opinion positively asserted in a mining paper, and he believed it had been a somewhat popular fallacy that such was the case. He perhaps should not have mentioned this as not being strictly applicable to that paper, but experiments would show that an obstruction or heavy fall did not in any way affect the water-gauge.

The Rev. G. M. CAPELL (Passenham), with regard to that question, wished to say that it very much depended where the water-gauge on the fan was placed. If the quantity of air was diminished the water-gauge was affected in the fan drift, but not so much in the inlet of the fan. What he alluded to was that a water-gauge pipe placed close to the fan inlet gives a water-gauge due to velocity, and keeps up the guage, when actually the resistance may have dropped. He had noticed it in several cases. He always advised, in comparative experiments, that a water-gauge should be placed close to the inlet and another in the fan drift. The difference would show any obstruction, and would show whether the speed of the air was increasing or diminishing.

Mr. M. WALTON BROWN (Newcastle-upon-Tyne) said when the ventilation in any mine was increased the depressions corresponding to the natural ventilation, and that due to artifical means, rapidly changed their relative values. The depression produced by natural means was even lessened, because the air passing more rapidly through the mine did not increase so much in temperature, because the density of this greater volume of air was less affected by mixture with gases, and because it contained a smaller proportion of water-vapour. The water-gauge produced by artificial means must therefore increase more rapidly than the propor-

tion represented by the square of the volumes or velocities. The lowering of the temperature, owing to the increased velocity of the air, was never very appreciable, and it was therefore difficult to appreciate the diminution, due to these causes, of the water-gauge produced by natural means. The depression due to natural means might consequently be considered as uniform for all velocities of the current, when the external temperature remained sensibly constant. The amount of aid afforded to ventilation by natural means could be calculated from the results of two experiments :—(*a*) The volume of air Q produced when no artificial aid was employed ; and (*b*) the volume $Q_{,}$ produced by mechanical means when the water-gauge h had a known value. If $h_{,}$ be the water-gauge produced by natural means, the given ratios are—

$$h_{,} : h_{,} + h :: Q^2 : Q_{,}^2,$$

and

$$h_{,} = h \frac{Q^2}{Q_{,}^2 - Q^2}.$$

When the action of the ventilator or furnace cannot be suspended in order to ascertain the volume of air produced by natural means, any two experiments made under different heights of water-gauge produced by artificial means may be employed. Let $h_{,,}$ and $Q_{,,}$ be the depression and volume obtained in the second experiment upon the ventilation, then—

$$h_{,} + h : h_{,} + h_{,,} :: Q_{,}^2 : Q_{,,}^2,$$

whence

$$h_{,} = \frac{h_{,,} Q_{,}^2 - h Q_{,,}^2}{Q_{,,}^2 - Q_{,}^2},$$

and this value may be either plus or negative. The effects produced by natural means on the ventilation of a mine will be seen from the following example :—In a mine, 50,000 cubic feet per minute are produced under 1·50 inches of water-gauge and 100,000 cubic feet of air under 8 inches of water-gauge by artificial means, then—

$$h_{,} = \frac{8\ (50{,}000)^2 - 1{\cdot}50\ (100{,}000)^2}{(100{,}000)^2 - (50{,}000)^2}$$
$$= 0{\cdot}666 \text{ inch of water-gauge.}$$

In experiments for the determination of this element, great care must be taken to ensure the accuracy of the measure of the volume. Thus, if the volume had been taken at 103,000 cubic feet per minute, then—

$$h_{,} = \frac{8\ (50{,}000)^2 - 1{\cdot}50\ (103{,}000)^2}{(103{,}000)^2 - (50{,}000)^2}$$
$$= 0{\cdot}4999 \text{ inch of water-gauge.}$$

Or an error of 3 per cent. in the measurement of the volume alters the value of $h_{,}$ more than 25 per cent. Take a mine, which is now ventilated by 50,000 cubic feet, under 1·50 inches of water-gauge, and which, owing to outbursts of gas, must in future be ventilated by 115,500 cubic feet

of air per minute: a mining engineer, who did not take the aid afforded by natural ventilation into account, would erect a fan capable of producing a vacuum measured by—

$$h_w = 1{\cdot}50 \frac{(115{,}500)^2}{(50{,}000)^2},$$
$$= 8{\cdot}004 \text{ inches of water-gauge.}$$

It has, however, been shown that 8 inches of water-gauge, even when aided by the natural depression, only produces a volume of 100,000 cubic feet, or a deficiency of 15,500 cubic feet per minute. The ideas he (Mr. Walton Brown) had set forth were probably well known to the members, and he had only re-stated them to show Mr. Southern that the three propositions upon which he based his paper were not generally accepted.

Mr. A. SOPWITH (Cannock) said there was great difficulty in ascertaining correct water-gauges. Some years ago he made a measurement of the pressures throughout his mine by means of an aneroid barometer, instead of using the water-gauges; and in that case with delicate experiments he was able to walk about the mine and practically determine the pressure of the air and see the difference of gauges throughout the mine. The only source of error was in case of any variation or difference in the atmospheric pressure during the time of the experiments.

Mr. COCHRANE (Newcastle-upon-Tyne) said the water-gauge placed in a proper position at the intake of a fan expressed the whole work of the fan, and did not indicate any work behind it. It gave the actual work the horse was doing but not that of the donkey. He thought this principle required to be insisted upon, as the total ventilation might be due to many other causes than the fan alone.

Mr. W. SPENCER asked Mr. Cochrane if he disregarded the natural ventilation entirely?

Mr. COCHRANE—No, quite the contrary. The water-gauge indicated on the fan inlet was the work done by the fan and did not include anything done behind the fan, whether by natural ventilation or otherwise.

Mr. T. A. SOUTHERN (Derby), replying to the discussion, said, Prof. Lupton had raised the objection that the momentum of the air would prevent an accurate reading of the water-gauge when the air-current was suspended in the way suggested. In reply to this, he would say that the air-current would lose its momentum altogether in a few seconds. He thought they had all noticed that fact, when main doors had been opened and suddenly closed; the sound of the sighing of the wind through the crevices showed that the increased pressure due to the momentum, existed

for only a few moments after the doors were closed. He might mention that this point was raised in a similar manner some forty years ago, before a Parliamentary Committee enquiring into the merits of the steam-jet, by Mr. Gurney, who asserted that the momentum of the air-current passing in a mine was such that it could not possibly be brought suddenly to rest by the closing of a wooden door. His words were, "The long line of air—the elastic rope through the galleries of a coal mine—is of considerable weight, 5 or 6 tons a mile, and 20 miles of passages would amount to 100 tons, which could no more be stopped than could a railway train;" from which it appears that Mr. Gurney, whilst using the word "elastic" had ignored the elasticity of the air. From Mr. Cochrane's remarks he gathered that he considered that the influence of the difference of temperature in the shafts was duly taken into account, and was not disregarded in calculations relating to the ventilation of mines, in which case, this paper would be altogether unnecessary. He could assure him, however, that he knew a great many cases in which it had been entirely ignored, and only a small number of instances in which it had been taken into account. Mr. Cochrane said, "If they had a horse and a donkey pulling a cart, they must not forget the donkey." This was a very good illustration, but his reply would be that the donkey was, in this case, an invisible donkey. They could see the fan on the pit bank doing its share of the work, but the shaft temperature doing its work had no machinery about it, nor anything substantial by which it could, in the same way, assert its existence, and therefore its effect was forgotten. Mr. Spencer had called attention to what was undoubtedly a popular fallacy in connexion with the water-gauge; and he believed this fallacy had been promulgated by the small treatise on "Mine Ventilation," by the late Mr. J. J. Atkinson. At the manager's examinations it was at one time common for candidates to be asked what effect a fall in the return airways would have upon the water-gauge. Now he would admit at once, that if a very large fall occurred, and greatly impeded the ventilation, it would cause an increase of the water-gauge; because, with a fan, the decrease of the quantity of air would cause the fan to run faster, so long as it had the same supply of steam to the engine, and its increase of speed would cause an increase in the water-gauge; and, with a furnace, the reduced quantity of air would be heated to a higher temperature, and this also would result in an increased water-gauge; but it must be a very unusual fall in an airway, which would so greatly obstruct the whole ventilation of the mine, as to produce a perceptible effect upon the water-gauge. The examiners had, however, intended it to be supposed that the water-gauge might be used to show when a fall had taken place in an airway, by indicating, as it has

been put, the increased drag or resistence to the air-current. Now, what mining engineer was there to-day who would seriously make such a statement, and yet it was but a few years since this idea was commonly entertained. So far as he could gather from the remarks made by Mr. Walton Brown, the cases he cited were all cases of compound ventilation, in which the fan was aided by a difference of shaft temperature, and his remarks seemed to support the statements made in this paper. Mr. Brown's first suggestion of stopping the fan and measuring the air which then circulated naturally was not a satisfactory and accurate method of ascertaining the true influence of shaft temperature, because the temperatures in the shafts would generally be very different when the fan was stopped, from what they were when the mine was at work under normal conditions. He agreed with Mr. Cochrane that the water-gauge on the fan drift, taken in conjunction with the total quantity of air passing, showed the useful work which was being done on the air by a fan; but that statement required qualification, for this reason: if the fan was assisted by a difference of shaft temperature, it was not correct to give the fan credit for producing the whole quantity of ventilation which was passing through the mine. This was a point of importance when comparing one fan with another, because, wherever the ventilation was assisted by a difference of shaft temperature, the quantity of air passing through the fan was thereby increased, and there could be no doubt that the useful effect of the fan would thus be increased also, just as, on the other hand, if the quantity of air passing through the mine was very small, owing to very long and contracted airways, the useful effect of the fan was thereby decreased.

Mr. J. B. Simpson (Newcastle-upon-Tyne) in proposing a vote of thanks to Mr. Southern for the paper, hoped he would slightly modify some of the sentences. He said certain propositions were "extensively accepted and relied upon." That should be qualified, as Mr. Cochrane said there was a great deal of work done by the donkey. At Cwmaman Mr. Southern said the temperature was 66 degs. in the downcast and 109 degs. in the upcast, which would represent a volume of at least 20,000 or 30,000 cubic feet of air, and this result was a proof of the application of Mr. Cochrane's remarks.

Mr. H. Lewis seconded the vote of thanks, which was agreed to.

The meeting then adjourned for luncheon.

The Secretary read the following paper, after the members returned, by Mr. J. C. B. Hendy on "Experiments upon a Waddle Fan and a Capell Fan Working on the Same Mine at Equal Periphery Speeds, at Teversal Colliery":—

EXPERIMENTS UPON A WADDLE FAN AND A CAPELL FAN WORKING ON THE SAME MINE AT EQUAL PERIPHERY SPEEDS, AT TEVERSAL COLLIERY.

By J. C. B. HENDY.

For the past twenty-four years the Teversal colliery has been ventilated by means of an open-running Waddle fan of the old type. This fan having become practically worn out, and the casing and vanes requiring almost entire renewal and repairs, a Capell single-inlet fan, designed to give a larger volume of air, has recently been erected to supersede the Waddle fan. An opportunity was thus afforded of experimenting with a Waddle fan and a Capell fan working on the same mine.

The Waddle fan is 30 feet in diameter with a 12 feet inlet, and is 37 inches wide at the inlet and 16 inches wide at the periphery. It is driven by a horizontal engine having a cylinder 24 inches in diameter, and 3 feet stroke, with ordinary slide-valves. The cost of this fan and engine would be about £800, exclusive of brickwork.

The Capell fan is 16 feet in diameter and 6 feet 6 inches wide, with a single inlet 8 feet 9 inches in diameter, and évasée chimney having an area at the top of 160 square feet, and at the base of about 70 square feet. It was designed to give 200,000 cubic feet of air per minute at 190 revolutions, with a water-gauge of 3 inches. This fan is driven by a pair of vertical engines, constructed to run 200 revolutions per minute, with a steam pressure of 45 lbs. to the square inch. These engines work direct on to the main shaft, and have cylinders 18 inches in diameter, with 15 inches stroke, and slide-valves. The fan-shaft, 9 inches in diameter and 10 feet long, is coupled to the engine-shaft on the inside of the engine-house. The cost of this fan with chimney and engines was £960, exclusive of masonry and brickwork.

The shafts are 217 yards deep to the Top Hard seam. The downcast is 14 feet in diameter and the upcast 11 feet in diameter, coals being drawn at the downcast pit only.

There are two steam hauling-engines in the pit with condensers, as well as a large Hathorne-Davey pump, and hauling-engines and pumps worked by compressed air, but all of these were standing when the experiments were made.

The experiments were made with the fans running at equal periphery-speeds, the speeds being taken continuously during the tests with a speed indicator, and checked by counting with a watch. The diagrams were taken with a Richards indicator, and the air measured by an air-meter, both of which had been previously tested. Two water-gauges were used, the ends of the tubes being fixed about 25 feet from the inlet of each fan, parallel with the air-currents; the orifice of each tube was padded with cottonwool, and covered with four layers of flannel bound tightly over the ends. The air was measured in the return airway in the mine near the bottom of the upcast shaft, in the following manner. A straight and even part of each return airway was chosen, and the area measured; a rod was then fixed across the middle of each airway and a mark made on the centre of each rod on which the air-meter was held for each measurement, as shown in Fig. 1, Plate XXI. Three readings, each of a minute's duration, were taken in the several returns for every experiment. The measurements were thus all made in precisely the same manner, and at exactly the same point in the same return airway for the two fans.

It will be seen from Table A that there is not much difference in the percentages of useful effects given by the several tests with the respective fans, the highest being 55 per cent., which, in each instance, was obtained when running at the lowest periphery-speed, viz., 94 feet per second. With the exception of the second experiment, the Waddle fan produced a higher water-gauge than the Capell fan, but the volume of air produced by the former was considerably more in each instance than was produced by the latter. At a periphery-speed of 102 feet per second the water-gauge was the same for each fan, viz., 1·70 inches, but the Waddle fan produced 103,647 cubic feet of air per minute with this gauge, against 97,194 cubic feet given by the Capell fan.

Table B records the quantity of coal used and water evaporated, which shows that the Capell fan, as might be expected, being a new one, was most efficient.

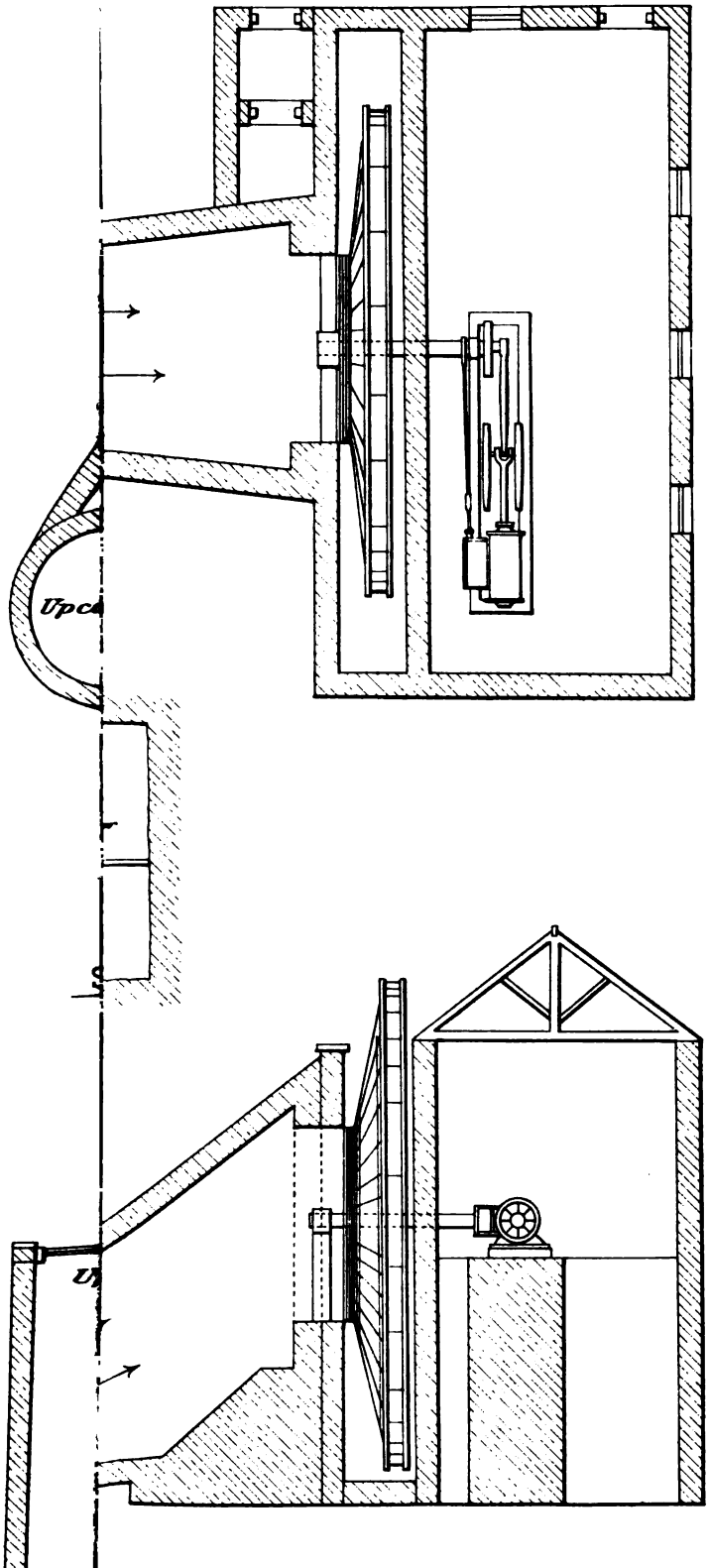
Figs. 2 and 3, Plate XXI., show the position of the two fans. The Capell fan was erected between the Waddle fan and the upcast pit, but, owing to want of space and the proximity of the boilers to the site on which the Capell fan was erected, a brick pillar 2 feet wide and 26 feet long was built in the middle of the fan-drift to support the end of the fan-shaft. The Capell fan perhaps suffers somewhat from this circumstance, as the air-current turns sharply into the inlet at a contracted part of the drift, while it has a straight lead to the Waddle fan.

TABLE A.—RESULTS OF EXPERIMENTS WITH THE CAPELL AND WADDLE FANS, AT TEVERSAL COLLIERY, DECEMBER 10TH, 1892.

No. of Experiment.	Description of Fan.	Water-gauge.		Barometer.		Thermometer.			Revolutions of Fan per Minute.	Periphery Speed of Fan per Second.	Volume of Air per Minute, Measured in the Mine.	Mean Pressure of Indicator Diagrams.		Power in the Air.	Indicator Power of Engine.	Efficiency.	Boiler Pressure, per Sq. Inch.
		Fan Drift.	Separation Doors.	Surface.	Mine.	Surface.	Mine.	Fan Drift.									
		Inches.	Inches.	Inches.	Inches.	Degrees.	Degrees.	Degrees.		Feet.	Cubic Feet.	Lbs. per Sq. In.		H.-P.	H.-P.	Pr. cent.	Lbs.
1	Waddle ...	2·05	1·95	28·74	29·80	38	66	63	70	109	108,501	11·6		35·04	66·79	52·4	50
2	Do. ...	1·70	1·60	28·64	29·79	33	64	62	65	102	103,647	9·8		27·75	52·39	52·9	48
3	Do. ...	1·50	1·45	28·73	29·77	34	63	62	60	94	98,878	8·6		23·37	42·43	55·1	45
												Right Cyl.	Left Cyl.				
4	Capell ...	1·40	1·30	28·64	29·75	32	63	62	113	94	88,045	8·0	8·2	19·42	35·28	55·0	45
5	Do. ...	1·70	1·55	28·63	29·70	31	63	62	122	102	97,194	9·7	11·0	26·03	48·68	53·5	45
6	Do. ...	1·90	1·75	28·63	29·67	31	62	62	131	109	101,747	12·0	12·4	30·46	61·60	49·4	45

TABLE B.—CONSUMPTION OF COAL AND WATER EVAPORATED BY TWO LANCASHIRE BOILERS, 7 FEET BY 30 FEET, SUPPLYING STEAM TO THE CAPELL AND WADDLE FANS, TEVERSAL COLLIERY, ON DECEMBER 10TH, 1892.

No. of Experiment.	Description of Fan.	Duration of Experiment.	Periphery Speed of Fan per Second.	Temperature of Feed-water.	Boiler Pressure per Square Inch.	Coal used per Hour.	Water Evaporated per Hour.	Coal used per Hour per Indicated Horse-power of Engines.	Coal used per Hour per Horse-power in the Air.	Water Evaporated per Lb. of Coal used.	Coal used per Week.	Cost per Week of Coal used at 3s. per Ton.
			Feet.	Degrees.	Lbs.	Lbs.	Gallons.	Lbs.	Lbs.	Lbs.	Tons.	£ s. d.
1	Waddle	1 hour	109	60	47	1,064	798	15·9	30·3	7·5	79·8	11 19 4
2	Do.	do.	102	60	47	840	670	16·0	30·2	7·9	63·0	9 9 0
3	Do.	do.	94	60	47	728	515	17·1	31·1	7·0	54·6	8 3 9
4	Capell	do.	109	60	50	896	700	14·5	29·4	7·8	67·2	10 1 7
5	Do.	do.	102	60	50	672	650	13·8	25·8	9·6	50·4	7 11 2
6	Do.	do.	94	60	50	560	505	15·8	28·8	9·0	42·0	6 6 0


Upc

It should be mentioned that, owing to the engine-bearings heating, it has not been possible to run the Capell fan at a speed exceeding 135 revolutions per minute, but a higher efficiency may be expected, as claimed by the inventor, when the Capell fan is run at its maximum speed. The Waddle fan, however, after running constantly for nearly twenty-five years, still gives results which prove that it is a well-tried and worthy servant.

The cost of oil, waste, etc., for the Waddle fan, running at 70 revolutions per minute, is 3s. 8d. per week; the Capell fan has not been running long enough to enable a correct estimate to be made.

The Rev. G. M. Capell (Passenham) said that on November 5th, 1892, Mr. Hendy sent him the following results of an experiment on the Capell fan at Teversal colliery:—

Revolutions per minute, fan	110
Mean pressure of indicator diagrams, right cylinder...	8·5 lbs.
Do. left cylinder	9·8 lbs.
Do. average	9·1 lbs.
Periphery speed of fan, per second	90·2 feet
Water-gauge, fan drift	1·60 inches
Do. separation door	1·40 inches
Power in the air	23·90 horse-power.
Indicated power of engine	39·10 horse-power.
Efficiency	61·10 per cent.

He deprecated the manner in which Mr. Hendy had measured the quantity of air—simply putting an anemometer in the centre of the drift, and taking the results so obtained as the mean speed. This was an entirely unreliable way of getting the quantity of air passing in any given time. Mr. Piggford had made some later experiments on the fans at Teversal collieries on February 20th, 1893, with the following results:—

	Capell Fan.			Waddle Fan.	
Revolutions of fan per minute	135	100	...	72	52
Water-gauge, fan drift, inches	1·9	1·0	...	2·0	1·0
Do. drift door, inches	2·2	1·5	...	—	—
Velocity of air, feet per minute	1,484	1,204	...	1,314	1,117
Volume of air, cubic feet per minute	116,494	94,562	...	103,201	87,729

These experiments were all made on the same pit and under the same conditions, the mine being at work. The area of the place of measurement

was 78·54 square feet. In previous experiments there was no steam in the drift; but in Mr. Piggford's experiments it was present. The drift gauge was used for comparison in Mr. Hendy's paper, and did not show all the work done by the fans in drawing the air to the obstructed inlets, and the calculations of useful effect on the drift-gauge are faulty from the same cause. Now, the difficulty which arose in the case of comparative experiments, as he said before, was whether or not the water-gauge used was the same in all cases. In these cases Mr. Piggford can answer for it; the water-gauge was taken at the same point in the case of both fans. When the water-gauge was taken close to the inlet in open-running fans, it did not affect it in the same way as in closed fans. The experiments recorded in the paper were so thoroughly opposed to those he had previously received from Mr. Hendy that there must have been some error in observation, and he had not the least doubt that if Mr. Hendy repeated the experiments in the same way he would have found exactly the same results as Mr. Piggford.

Mr. Henry Lewis (Nottingham) said he would, however, like to say a few words in favour of the much-abused Waddle fan. He had one running for seventeen years at Linby collieries, 40 feet in diameter, at 40 revolutions per minute, and they got 200,000 cubic feet per minute, at 1½ inches of water-gauge. He did not attach very much importance to the water-gauge. He looked at the quantity of air produced, and was perfectly satisfied with the result.

Prof. Lupton (Leeds) said he had looked at that paper with very great interest, and was very much struck with the comparative results of the Waddle and Capell fans in the same drift, and with approximately the same results for each machine. This result agreed with the observations which had been made during the last twenty-five years on most fans that have been produced before the public. Sometimes they gave high results when all the circumstances of the observations were favourable. At other times, with unfavourable circumstances, they got low results; at other times, average results, such as were evident in this case. He quite agreed with Mr. Capell as to the great difficulty there was in getting accurate water-gauge results and measuring air results. Some time ago he, in a paper, wrote at length on the subject and advised the method of dividing the air-current into several parallel compartments by boards, and taking concurrently the air speed in each channel or compartment. He was a patentee like Mr. Capell; his (Mr. Lupton's) fan gave 70 per cent., and he got a water-gauge higher than the theoretical water-gauge, which was also done by the Guibal and other fans.

Mr. WADDLE (Llanelly) said he knew nothing of Mr. Piggford's experiments before he entered the room, when Mr. Capell had read certain figures and had referred to the presence of steam in the drift. The Waddle fan at Teversal colliery had been working twenty-five years in steam going up the upcast shaft, and consequently the fan and blades were in a more or less imperfect condition. The present water-gauges and volumes were much less than if the fan had been one of the improved Waddle type. With reference to Mr. Hendy's method of measuring the air, since this was exactly the same for both fans, it would give an accurate comparison between them.

Mr. COCHRANE said he had given the subject much attention, and it was worth everybody's while to devote their time to it. Quite outside of the respective merits of the Waddle, Guibal, or Capell fan, the accuracy of water-gauge records was all important. Whether discussion arose on that subject or the efficiency of different fans, it was an important matter to be brought before the Institution, and he had very great pleasure in proposing a vote of thanks to the writer of the paper.

Mr. J. B. SMITH, in seconding the vote of thanks, said he noticed in the paper that there was some divergence in the weights of water evaporated per pound of coal.

The vote of thanks was carried unanimously.

CORRESPONDENCE.

Mr. J. C. B. HENDY wrote in reply to Mr. Capell's remarks as to the manner of measuring the air in the experiments, that it was almost impossible to measure the air correctly in the fan-drift, owing to its being divided by a brick pillar, and to the awkward position of the two fans. He believed that the measurements taken at exactly the same points in the return airways for each experiment gave a true comparison of the quantities of air produced in the mine by the two fans. Mr. Capell stated that in a previous test with the Capell fan he (Mr. Hendy) found the efficiency to be 61 per cent.; but he omitted to state that this result was obtained when measuring the air in the fan-drift and running the fan at a less speed; whereas the 55 per cent. was based on the quantity of air measured in the mine. This was fully explained to Mr. Capell at the time, yet he thinks proper to attribute the difference to errors in observation instead of to the true cause. In his (Mr. Hendy's) experiments two water-gauges were used, and their positions remained unaltered during the tests upon each fan; and the readings of each water-gauge were compared in every experiment and found to agree. He could say nothing as to Mr.

Piggford's experiments, which were referred to by Mr. Capell, as the conditions as to temperature and the modes of making the measurements were not stated; but he might remind Mr. Capell that his (Mr. Hendy's) experiments were made with the fans running at the same periphery speeds, and not especially at the same water-gauges; also that no steam was being exhausted into the upcast shaft, and that the mine was not at work. He thought Mr. Capell ought to be satisfied with the results, and he had no doubt that when the Capell fan could be run at the speed for which it was designed, a higher efficiency would be obtained; but at the same time he was inclined to think that a Waddle fan of modern design would give equally good results if working on the same mine and under the same conditions.

Prof. LUPTON then read the following paper on "Spontaneous Combustion in Coal-mines":—

SPONTANEOUS COMBUSTION IN COAL-MINES.

By ARNOLD LUPTON.

In submitting the following paper on "Spontaneous Combustion in Coal-mines" the auther does so rather in the hope of eliciting valuable information in the discussion than with any expectation of conveying knowledge to those members whose experience has been gained in mines liable to this species of catastrophe. The few remarks submitted are the result of knowledge gleaned in his experience and travels in districts most liable to spontaneous combustion, such as Leicestershire, Warwickshire, Staffordshire, and in other districts where it is less frequent, such as Yorkshire, Derbyshire, and Nottinghamshire. He is, however, also indebted to the various papers and writings of others, published in the Proceedings of various scientific bodies, and to his private correspondence with mining engineers and chemists, whose assistance he gratefully acknowledges.

Most of the dangers and difficulties encountered in a mine can be overcome in certain well-known ways; water can be raised by pumping-engines; gas can be carried away by ventilation, and the danger obviated by safety-lamps; faults can be passed through by sufficient expenditure of money; but spontaneous combustion can hardly be prevented, and when once begun it is sometimes impossible to stop it, except by some process that involves the entire closing of the colliery.

Spontaneous combustion of coal, or as it is sometimes, and perhaps more correctly called, spontaneous ignition, means the firing of coal without the direct application of a lighted match or other flame.

In some cases the cause of spontaneous ignition is obvious. Take for instance a ventilating-furnance built in a seam of coal. The heat from the fire makes the brickwork hot, and raises the temperature of the coal or coal-shale adjoining to the point necessary for ignition, which is between 700 degs. and 800 degs. Fahr. The remedy for this kind of spontaneous ignition, if it can be so called, is very simple, and that is to separate the coal or coal-shale from the furnace by a passage conveying a current of cool air. It is not enough to provide an air space, because air is as easily heated as any other substance; it is necessary to provide a

constant current so that there may be always cool air between the arch containing the furnace and the arch supporting the coal or other strata.

But spontaneous ignition often takes place under conditions where there is no fire or any apparent source of heat equal to 700 or 800 degs. Fahr. Any large heap of ordinary bituminous coal is liable to spontaneous combustion—say, one, 10 feet thick and 30 or 40 feet square. The larger the heap and the smaller the coal, the greater the liability to fire. Thus a heap of coal built up of large blocks of hard coal 15 feet high will probably not take fire, but a heap of slack of equal height from the same seam would probably take fire.

If a little artificial heat is applied to a very small heap of slack of, say, 2 or 3 tons, it is very liable to fire. Suppose, for instance, there is a brick flue carrying the hot gases from a fire to a chimney and 3 or 4 tons of slack are tipped against this flue, it is very likely to take fire. The reason of this again is very obvious. The outside of the boiler-flue feels cool, because it is exposed to the wind, but the inside of the boiler-flue is very hot, perhaps 800 degs. Fahr. or more in temperature. When the slack covers the external wall the heat is no longer carried away, and the outside of the brickwork in a few days will become nearly as hot as the interior, whose heat is quite sufficient to set fire to coal.

There are, however, other cases less easily understood. For instance, if a heap of coal be laid over a steam pipe it will soon take fire, though the temperature of the steam and the pipe never exceeds 350 degs. Fahr., which is less than half the temperature required for the ignition of coal. But this is not so curious as the ignition of coal where there is no artifical heat of any kind.

Coal is not the only substance that will enflame without the application of a match. If newly-burnt charcoal is ground up, it will take fire. Rags or waste soaked with vegetable oil and put in a heap will take fire. Very finely-divided iron or lead will also burn. Phosphorus takes fire with the warmth of the hand. The compression of air, by means of a piston in a syringe, will give heat sufficient to ignite ether or tinder soaked in a solution of nitre.

In coal-mines there is a general liability to spontaneous combustion in the majority of the coal-fields of Great Britain; in some districts it is exceedingly rare, and in others it is exceedingly common. Experience shows that it is very rare in thin seams and very common in thick seams; and that in seams of equal thickness it is more likely to occur where a large proportion of the seam is left in the mine, either as slack or as roof-coal. In fact, spontaneous combustion, as a general rule,

occurs in those mines where a great deal of small and broken coal is left in the goaf, and is hardly, if at all, known in those mines where all the coal is sent out and where there is no coal in the mine except the solid uncut seam or large and uncrushed pillars.

The districts where gobfires are most common in Great Britain are South Staffordshire, West Leicestershire, and Warwickshire.

In South Staffordshire the Ten-yard coal is worked pillar-and-stall. It is got in panels, locally termed "sides," say about 80 to 100 yards square, in which area there would be sixteen or twenty pillars about 10 yards square. The whole of the coal between the pillars and the ribs separating the sides or panels is got, with the exception of the roof-coal, say a yard in thickness, which is left because of the danger of trying to get it. A good deal of slack and of coal mixed with dirt is also left in as being valueless. In course of time the roof falls and a good deal of coal no doubt breaks off the sides of the pillars. Thus considerable heaps of coal, dirt, and slack are formed, and in a short time these heaps frequently get very hot, and unless precautions are taken they would burst into flames.

The usual method of preventing this is to put stoppings in all the roads leading into the "side" so as to prevent any fresh air having access; thus any combustion that begins speedily exhausts the oxygen, and further combustion is so prevented. The slow combustion, however, so far as it takes place, has the effect of making the mine in that part exceedingly hot. In some places air draws through cracks in the ribs, so that a more rapid combustion can take place and great heat is produced. The main roads leading past these hot districts are sometimes arched with brickwork to assist in the exclusion of the air and to maintain a good road. Sometimes the brickwork gets so hot that it cannot be touched. As a general rule, however, the exclusion of the air stops the combustion. After the whole of the mine has been worked the sides are often re-opened to get the pillars and ribs.

In Leicestershire the coal is worked in two ways: sometimes by long-wall and packed gates, and sometimes by heading out and working back. Where the packed gates are used, the packs are made impervious to air by means of wax walls. These wax walls are made of clay, which has been worked to the proper consistency for making bricks, and is sent down in large lumps about 9 inches square and 18 inches long, and is built up into walls on each side of the gate-road, while small dirt is packed on each side of the wax walls. These walls being soft have no strength to support the roof, and the packs are made to a great extent of wood. The

wood used is the small branches of trees cut into lengths of about a yard and built into square piles: it is commonly called "brattice wood." These timber packs are placed about 4 feet apart, and the space between them is filled up with stone made from the ripping of the gate-roads. In this way the goaf between the gate-roads is kept from the air-current; the only place where the air comes in contact with the goaf is close to the working-face. In order to prevent the air from getting back into the goaf near the working-face, the ventilation is kept as slack as is consistent with safety. The face is moved forward pretty fast, say 2 or 3 yards a week, and consequently the goaf near the face has not time to heat. If, however, there should be a stoppage, owing to slackness of trade or a strike, the goaf would take fire at the face; and to prevent that, the wax wall has to be carried along the face from gate-road to gate-road.

Mr. Alfred Ely, in a valuable paper read before the Chesterfield and Derbyshire Institute, in April, 1877, describes another method of excluding the air from the goaf at the face. He packs a bank of dirt all the way along the face on a slope from the roof to the floor. The face of this slope he then covers with a layer of sand 6 inches thick, which has the same effect as a clay wall in keeping out the air.

Where the system of heading out and working back is employed; no wax walls are required, except during a stoppage, and then a wax wall is run along the face between the coal and the goaf, so as to exclude the air from the goaf.

In some collieries the manager arranges as far as possible to finish off a district before the summer when trade is slack, and then he opens out a new district ready for the ensuing winter; the point to be aimed at being that the air-current must never pass over or through heaps of slack or broken coal as in a goaf.

In Warwickshire the liability to spontaneous combustion is met by working the face as quickly as possible. For this purpose a number of coal-getters are concentrated in a small area. Wherever practicable, the mine is worked by heading out in the solid, and then bringing the coal back.

In many Warwickshire mines the bulk of the coal lies to the dip of the shaft; in this case the headings are driven down to the dip boundary, and then the coal is brought back, the goaf being allowed to fill with water.

Both in Warwickshire and Leicestershire a considerable portion of the coal in the seam worked is not got, being of slightly inferior quality to

the coal that is got. Also a good deal of slack is left in the mine, so that there are great heaps of slack and broken coal.

But the question now arises, how can this coal take fire, considering that the natural temperature of the earth in these mines is, say, from 60 degs. to 65 degs. Fahr.?

The explanation formerly given was that the iron pyrites, that is, disulphide of iron ($Fe\ S_2$), which is often found in the coal and in the shales, is decomposed by the oxygen of the air, and that this decomposition is accompanied with heat. It has been found by experiment that in some cases great heaps of shale, containing a large percentage of iron pyrites, have taken fire through the decomposition of the pyrites. But the amount of pyrites in the coal-mines is too slight to have any appreciable effect in heating the coal, and this theory is now given up by those who have most studied the question.

Prof. Vivian B. Lewes has made some valuable contributions to the knowledge of this subject in papers read to the British Association in 1891 and subsequently to the Society of Arts. He states that it has been demonstrated by Richters that newly-cut coal will absorb oxygen; some coal absorbing $1\frac{1}{4}$ times its own bulk, and other coal 3 times its own bulk.

How the oxygen gets in and is compressed into the very small space it must occupy is another question, but there is no doubt that it does go in, and that active chemical decomposition of the coal takes place, forming carbonic acid gas and water, and that this decomposition is accompanied with considerable heat.

The hotter the mine the more rapid the decomposition, so that the process of heating when once begun goes on at an accelerating ratio, or in geometrical progression provided there is a sufficiency of oxygen to keep up the combustion.

In mines where the air is successfully kept from the goaf, however, the heat rises up to a certain point sufficient to make the mine very warm, but does not exceed that point, and then cools down again, because there is not enough air for further slow combustion.

The return air of a mine, the natural temperature of which is about 62 or 63 degs. Fahr., will probably be 70 degs., and in some places warmer still.

In order that the heat may get up to the point of combustion, it is necessary that the coal or slack should have no opportunity of cooling. In the case of a very large heap of slack the heat which is generated in

the centre cannot escape, and in the case of a small heap of slack, which is buried in the goaf of a mine, the heat there also is kept in by the cover of shale and roof. But, while the cover keeps in the heat it also excludes the oxygen, which is necessary for combustion; therefore the heating will arise from the oxygen which is taken into the coal before it is finally covered up by other coal or by falls of roof, and the heating proceeds from the centre of the heap outwards. But if, when the heat from the centre has reached the outside of the heap, there is a supply of fresh oxygen at the outside, the heap will rapidly take fire.

Where the workings in a longwall face are being moved rapidly forward the outside of the heap never gets hot enough to fire, because the heap is being continually lengthened and the old part of the heap is kept from the air by the wax walls on each side and the new stuff in front.

It is sometimes recommended, as a way of preventing spontaneous combustion, that the goaf should be cooled by strong ventilation.

There is no doubt that this cooling by ventilation will prevent a gob-fire, if it is thoroughly efficient. That it may be efficient it is necessary that there should be no large heaps of broken coal, because the wind cannot be forced through these heaps; and, as a general rule, it is found impossible to prevent combustion by cooling, so it has to be prevented by the exclusion of the air. The air-roads would have to be within a few, say 15, feet of each other to ensure effective cooling.

When every precaution has been taken it will happen, however, that the mine will catch fire in places, and unless these fires are immediately extinguished, the flames may rapidly extend to the whole mine. It is therefore necessary that the mine should be continually traversed and examined for any signs of combustion, which is usually detected by the condensation of moisture or the pungent odour from the heating mass.

In many cases, as soon as heating is discovered it is put out by simply digging out the hot part and sending it out of the pit, and in some cases, filling up the place with sand. It sometimes happens, however, that the mass of hot material is too large to be dug out and a sort of hand fire-engine has been used to pump water on to the fire, after which the combustible material is dug out and the place filled with sand.

In some mines water is laid on all over the mine under pressure, and is ready for extinguishing a fire from whatever cause it may arise.

In a great many cases the only way of extinguishing a fire is to build off the district in which it occurs. In this case, the stoppings are generally made by building a brick wall with mortar; this wall is sometimes

faced with a clay wall, which is kept damp, and constantly smeared to close all the openings, and so prevent air from drying it. Several stoppings are built a few yards apart, so as to reduce the chance of leakage past the walls. The burning coal in the enclosed area soon exhausts the oxygen, and then the fire goes out.

If, however, there should be any tendency due to the ventilating pressure of the mine for air to pass through this district, it is exceedingly likely that some air may find its way in and keep the fire smouldering, ready to re-light as soon as the stoppings are pulled down. Sometimes such a fire may smoulder for thirty years, and there are cases of underground fires that have lasted a longer period.

The only certain way of extinguishing a large fire is to submerge the mine or district of the mine under water: this is never resorted to until every other plan has failed.

Cases have happened where gobfires have not been even subdued by the stoppings built, but owing to air drawing through cracks in the coal pillars the fire has gone through the pillars.

In one mine known to the writer he has been told that the pillars of solid coal fired spontaneously not far from the upcast shaft, and before the fire was discovered it had reached proportions which made it hopeless to extinguish it. It was therefore necessary to close the pit, and the shafts were stopped by hanging scaffolds about 20 yards down by means of chains, and on to these scaffolds was put earth and clay, filling up the shaft completely to the top. The air being thus entirely excluded, the fire extinguished itself by burning up the oxygen, and subsequently the mine was re-opened.

Sometimes, the exclusion of the air from a district in a mine which has taken fire involves the building of a great length of brick wall, owing to the joints in the roof and coal permitting the air to pass; but by building all round the district a brick wall, which is dug into a trench in the floor and into a nick in the roof, the air is excluded to a sufficient extent to permit of the working of the colliery.

Where a main road has to be taken through a district which is hot, it is often best to arch it with brickwork, the arch being surrounded with sand. In order to prevent the air drawing through cracks in the floor, the archway is inverted, the invert also being laid on sand. The object of the sand is to cover up all small holes in the brickwork, or any cracks that may subsequently occur therein, and so prevent air drawing through. It must therefore be very carefully rammed into position. The inside of the wall may be lime-washed from time to time, to fill up the cracks in the wall.

If a fire in a mine once gets fairly hold of the coal in a place where there is a sufficient supply of air, the heat produces a great deal of gas from the coal which may form an explosive mixture with the air and thus a serious explosion may result.

Dr. BEDSON wrote that although he had nothing new to add on the subject of the spontaneous ignition of coal, there were one or two points to which he might refer in connexion with the subject. In the first place, there could be little doubt that the cause of the spontaneous ignition of coal was to be found in the inherent property of coal, by which it was able to absorb considerable volumes of oxygen, which at once did oxidizing work, leading to the production of carbon dioxide and water, the formation of which was attended by development of heat. Provided then that the heat be allowed to accumulate or be not too rapidly dissipated, the oxidation would be accelerated and the raising of the temperature of the coal to its ignition-point was only a question of time. He thought that the influence of iron pyrites must be regarded as of an entirely secondary character, its oxidation and consequent disintegration aiding, inasmuch as it resulted in the increase of surface exposed to the air. The question as to the temperature to which coal must be heated in order that it might take fire and burn was affected by the composition of the coal, its physical condition, the method of heating, etc. He would, however, like to point out that many years ago Fayol succeeded in igniting coals by heating them to a temperature of 180 degs. Cent. (356 degs. Fahr.), and in some experiments made for the North of England Institute of Mining and Mechanical Engineers, some six or seven years ago,* he (Dr. Bedson) succeeded in igniting coal-dust at a much lower temperature, viz., 140 to 150 degs. Cent. (284 to 302 degs. Fahr.). In these experiments the coal-dust was spread in an even layer on sheets of asbestos suspended in an air-bath, the temperature of which was carefully maintained at 140 degs. Cent.; jets of air were allowed to impinge on the dust, and in several experiments he was able to bring about the ignition of the dust in the course of an hour or so; the temperature of the bath remaining at 140 degs. Cent. As illustrating the influence of time as a factor in chemical change, he would mention that during the past summer when uncovering the steam-pipes at the Durham College of Science, Newcastle-upon-Tyne, the sawdust, which had been used as packing, was found charred to a considerable depth, and this at points some 30 or more yards

* *Trans. N.E. Inst. Min. Eng.*, vol. xxxvii., page 197.

from the boiler. Here a change had been produced in the course of time (some three or four years) at a comparatively low temperature, which would have necessitated a much higher temperature to yield the same effect in a shorter time.

Mr. EMERSON BAINBRIDGE (Sheffield) congratulated Mr. Lupton on his very able paper. It seemed to him that those gentlemen who had to manage mines in which clay-puddling was constantly required could only realize in a small degree what it was to manage a mine free from these dangers. Water and fire were two things a mine manager dreaded, but in his opinion there was no comparison between one and the other. Fire was very much more serious and dangerous. When water got into a mine it could be left at night until next morning, but with fire they could not leave it for a moment. In Mr. Lupton's dealings with spontaneous combustion, he appeared to have confined himself to the fact that there was spontaneous combustion, and not quite enough to the cause and the cures there are for it. He would be glad if he would give them some informamation as to how to prevent that peculiar combustion which many of them experienced on large heaps of small coal and shale on the surface. In small coal it took very few days for the heap to catch fire, and there was yet to be found a method of preventing it; it could not be stopped until it had burnt out, and it was often an intolerable nuisance. Then he hoped Mr. Lupton would more fully refer to the question of compressed oxygen which was quite new to him. If there was anything in it, it was certainly deserving of very serious consideration. His own experience in Warwickshire with regard to spontaneous combustion was evidently much milder than those cases to which their attention had been directed. They never had any more serious case than could be stopped by sand. That was always enough to arrest fire. He wished also to refer to the system Prof. Lupton had alluded to of working coal in Warwickshire. It seemed a perfectly model system, and by it they could get one rope round the whole of the roads, and have them all thoroughly accessible and perfectly easy for working.

Mr. BINNS (Netherseal) said he had had a great deal of experience in gobfires, and the paper was very interesting to the members living in South Derbyshire and North Staffordshire. It was difficult when simply listening to the paper being read to grasp all its facts and figures. Did Prof. Lupton state that only bituminous coals were liable to spontaneous combustion, and not brown coals and lignite. Because if so, such was not the case. The coals which belonged to the lignite and brown class were very much more liable to spontaneous combustion than bituminous coals

in England, and that point was explained by Prof. Clowes, of Nottingham, in a recent lecture, in which he said the moisture in coal was a large and important factor in this subject. He said that the coking coals were those in which spontaneous combustion very regularly took place. They did not here find coking coals more subject than non-coking. In that respect his experience was quite the contrary. As to the temperature required for ignition of coal he did not think anything of that, because he believed the first ignition was caused by certain hydrocarbons in the coal, which took fire at very low temperatures. What those were he did not know, but they looked to gentlemen who, like Prof. Lupton, enjoyed a life of professorial ease, to experiment and let others know. As regarded moisture being a sign of fire, he might state that six times in two years they had had continuous moisture coming on the roof and threatening fire. That was in an old bord—a narrow working which had been traversed by a road. It was usually necessary in similar cases to put in large brick arches of considerable thickness, but they thought they would try packs. They did so, and six times they had had moisture, so that they could sweep it off. They waited for the damp, but it never came. The moisture went back, but now and then came again and went back. They regarded that in their part of the country as a more delicate test than the nose of the manager. They always found moisture sooner than the gob stink. As regards pillar firing it was an absolute fact. He knew a case where a solid pillar of coal showed signs of moisture, and fire was taken out of that solid pillar. Whether that was due to the absorption of oxygen owing to the crushing of the pillar, and small coal being formed, which readily absorbed oxygen, he could not say; but he believed that coal contained some hydrocarbons which ignited at low temperature; but they knew nothing of the cause or the theory, they only knew how to prevent it.

Mr. W. Spencer (Leicester), as one who had had a good deal of experience, would like to make a few remarks. In the first place, the popular theory that "one must not have too much air in the pit," or you will have gobfires, he had proved in Leicestershire to be absolutely contrary to fact; in fact at one pit they were, some years ago, continually having gobfires. They were very deficient in ventilation. They sank another shaft and largely increased their ventilation, and since then they had scarcely had a gobfire at all. There was another point. Prof. Lupton thought the combustion was accounted for by the coal being left underground for packing. That might have something to do with the seriousness of it, but it did not account for it. He had not experienced

a considerable number of spontaneous fires in shaft pillars. They might be accounted for by pressure, as suggested by Mr. Binns. To extinguish the fires he had found flue-dust of more use than sand. It was most important to deal with all fires promptly and continuously.

Mr. W. F. Clark (Birmingham) said, having had some experience in working coal in South Staffordshire, he would like to say something with regard to flue-dust. He used it rather largely for the purpose of damping out fires, but in South Staffordshire the majority would not place as much reliance on flue-dust as on sand, neither did they think very highly of clay walls. In damping out fires he thought clay was practically useless. In a few hours it became quite dry, and the air passed easily through it. They found nothing so good as sand. With regard to pillars, if they were near the workings, there would undoubtedly be considerable pressure, and his experience had been that firing in solid coal was due to pressure, firing taking place in the fissures and cracks caused by the pressure. In the Thick Coal it was usual to leave large pillars to bear the weight, these occasionally cracked right through; and when left at night, probably before next morning the crack would be all aglow. That was a common occurrence in South Staffordshire. Prof. Lupton had referred to moisture, and said that was followed by the stink. That was so, but before they got the pungent smell, due to fire, sometimes there was another odour which was generally spoken of as being "old." An experienced colliery manager would often remark "It smells very old, and if we don't mind we shall have fire." He did not know how to better describe it. Mr. Binns had said he did not think heat mattered. He did. He quite agreed that it was a matter of the greatest importance that they should have sufficient air to keep the places cool. If they did not, they were helping to bring about spontaneous combustion.

Mr. J. B. Smith (Newstead) said in the Leen Valley they had some experience in gobfires. He believed the roof had a great deal to do with them. Some time ago he took a certain portion from the bind of the roof contiguous to where a gobfire had occurred, and made a small heap and put his thermometer in it, and he found the temperature rise. He once put some of the bind into a retort and distilled it—he did not know if Prof. Lupton had done that—and the fumes which were produced were most offensive. The smell of a gobfire sometimes resembled garlic, and he thought it was due to the decomposition of arsenides of iron in the bind. He would like to ask one question, was it not a fact that there was no experience of gobfires taking place where there was a white rock roof? He thought they were induced by a bind roof.

Mr. H. LEWIS said his experience was that they were caused by little ventilation. A great deal depended on the ventilation. If they had plenty of air they ran far less risk.

Mr. BINNS said he did not intend to say that ventilation did not matter, but that the point of ignition did not matter.

Mr. F. A. GRAYSTON (Tamworth) said it was generally accepted that a good ventilation of the workings assisted in preventing gobfires, but he would not recommend anyone to put much air into the gob itself. Prof. Lupton said the roads should be 15 feet apart—presumably one would be the intake, and the other the return air-road. In Warwickshire such an arrangement would create a gobfire at once, because the air would be drawn from one air-road to the other through the gob. He thought they should always make it a point to have the return air-road as distant as possible from the intake, because when the air was drawn through the gob it frequently caused fire. Where coal was got by gob-roads, he found a great source of danger to be at the rib sides; and to reduce this to the minimum, he packed the sides of the ribs as closely as possible, so as to exclude the air.

Prof. LUPTON thought his paper had been justified by the discussion. They had engineers from all parts of the country, and of the widest experience, giving the details of their very long experience. With regard to Mr. Bainbridge's question about some heaps of shale catching fire, that was a point on which he wanted further information from him, and on which he suggested he (Mr. Bainbridge) should give them a paper at some future time. With regard to the firing of shale in the presence of some of them, he spoke with some slight diffidence and some amount of trepidation. He was always under the impression that it was caused by waste ashes from the engine fire. He had heard an engineer say he had entirely stopped all fires of that kind by preventing hot ashes from being heaped on the shale-heap.

Mr. W. F. CLARK—If you come into South Staffordshire, you will find nearly every pit heap on fire entirely free from ashes.

Mr. SMITH—We have a large heap of thousands of tons on fire, and no ashes have been near it.

Prof. LUPTON said he granted the heaps were on fire, he knew them well, but could they be sure no light had been near them, not even a shovelful, if not a barrowful of hot ashes?

Mr. SMITH—Not even a teaspoonful.

Prof. LUPTON said he called then for a paper on the spontaneous ignition of shales for the enlightenment of professors "and others."

There were the burning cliffs of the Oolite said to be fired by the heat of the sun. As to lignites he had not had much experience in them, but he did not exclude them, although he alluded more to steam coal and anthracite. With regard to the firing of solid pillars it was a question which required fathoming. He was delighted to hear the opinions of Mr. Spencer, Mr. Lewis, and others, that ventilation was all that was required to stop gobfires, and pleased indeed to hear the remarks of Mr. Grayston that with air-roads as close together as practicable, say only 15 feet apart, that a good current of air would be certain to cause gobfires. He must leave them to settle it. He was also pleased to hear Mr. Binns' valuable contribution to the discussion and interested to hear his opinion as to hydrocarbons being important factors in spontaneous ignition.

Mr. SPENCER said Prof. Lupton misunderstood him when he said ventilation would entirely do away with gobfires. He said almost, not entirely.

Mr. JOHN STRICK (Madeley) thought they could not close the discussion of so able a paper without giving the author a vote of thanks. At the collieries he was connected with they found that ventilating the goaf caused gobfires, and in some places they allowed the goafs to fill with gas which prevented gobfires. Being fiery mines and liable to gobfires they worked in panels and had stoppings put in with only a doorway left open, ready to be closed if required. On one occasion a gobfire broke out at 7 a.m., and it was built off by 12 noon, which, considering the difficulty of getting materials to the spot, was quick work. If there was an obstruction to the air against a gob it was liable to fire. He knew of such a case where the air was obstructed, and the temperature rose to 90 degs., he set men at work night and day, and immediately the air was liberated the temperature began to fall. Then, in some places, they had from 3 to 5 feet of light shale, locally called hussle. This was very liable to fire, if left in the roads. He proposed that a hearty vote of thanks be accorded to Prof. Lupton for his paper.

Mr. A. G. BARNES (Chesterfield) seconded the vote of thanks. They had a large shale-tip on fire at the Grassmoor collieries, it became an intolerable nuisance, and they tried to mitigate it. They put a bridge up, and tipped on the other side. The two heaps were completely cut off, but the other was also soon on fire, although no ashes or fire had been near it.

Mr. H. R. HEWITT then read the following paper on "A New Method of Laying Coal-dust":—

A NEW METHOD OF LAYING COAL-DUST.

By H. RICHARDSON HEWITT.

The various methods of dealing with coal-dust have long occupied the minds of mining engineers; the writer is of opinion that the present rude methods of dealing with the accumulations of coal-dust in mines are far from being perfect; and any new suggestion showing how to minimize the danger of these accumulations will, he ventures to think, meet with the approval of the members.

It is an understood fact by every person connected with coal-mining that accumulations of dust on the floor, roof, and sides of underground roadways are a great source of danger. As to how far that danger surrounds us, the writer will not venture on an opinion, but awaits the final report of the Royal Commission on Coal-dust. This report when issued will contain reliable data to guide future researches into the matter, but the general opinion appears to be that water, in some form or other, is the only agent by which the evils from accumulations of coal-dust may be remedied.

Mr. Joseph Cunliffe, manager of the Awsworth colliery, near Nottingham, has invented a spray-maker, which appears to be, from an external view, an ordinary tap; its orifice, however, tapers from $\frac{5}{16}$ inch to a needle-point (Fig. 1). It is extremely simple in construction, and each one is tested up to a pressure of 1,000 lbs. per square inch. Water is ejected under pressure from the small hole, and should it become blocked at any time—a thing which will happen occasionally on account of the smallness of the aperture—the tap may be simply turned round, and the obstruction is sent out from the larger diameter by the pressure of the water behind it.

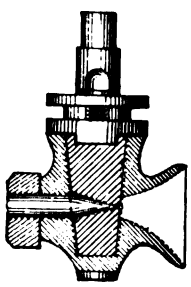


Fig. 1.
$\frac{1}{15^{th}}$ size

Experiments were carried out with this spray-maker, on August 13th last, in the Awsworth colliery, on the south main road of the Kilburn coal, 300 yards from the bottom of the downcast pit. The road was 9 feet 6 inches wide and 5 feet 9 inches high, and the air-current measured 6,336·5 cubic feet per minute or a velocity of

1·93 feet per second. The velocity of the air was low, and with a greater velocity of air the experiments would have been more demonstrative of effective results.

The pressure during the experiments was produced by means of a double-acting hydraulic hand pump whose dimensions were:—rams, 2 inches in diameter and 4 inches stroke. The working arm had a fulcrum of 6 inches and a leverage of 3 feet.

The spray-jets used were three in number (Fig. 2), fixed to throw the water horizontally from a 2 inches vertical pipe in the centre of the roadway, which was connected to the pump; the spray-making jets were placed 12 inches apart, and the pressure of water in the pipes was measured by a hydraulic gauge. Thermometers were placed 40 yards on the in-bye side, 40 yards on the out-bye side, and at the apparatus itself. All the thermometers were tested together in the same air-current, so that reliable results might be obtained. The temperature of the water throughout the experiments was 61 degs. Fahr., and the distance the spray was noticeable was taken by means of an ordinary mirror. A summary of the experiments is given below:—

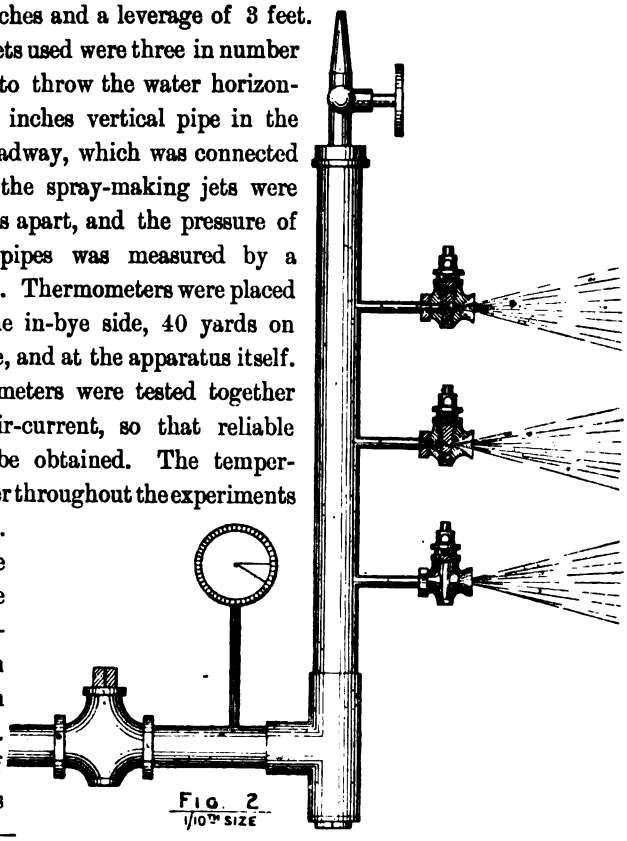


FIG. 2
1/10TH SIZE

Conditions of Experiment.	Time.	Temperatures Observed.			Pressure in Lbs. per Square Inch.	Distance in which the Spray was noticeable.	Quantity of Water Discharged.
		Out-bye.	Pump.	In-bye.			
	A.M. A.M.	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.		Yards.	
3 taps on	10· 0–10·15	63	63	62	260	45	3 gallons.
2 taps on	10·45–11· 0	62	62	62	400	35	2 gallons.
1 tap on	11·20–11·35	62	62	62	620	30	Over 1 gallon.

The pump was worked regularly at the rate of 7 strokes per minute, and the amount of water thrown out was found to be ½ pint per tap per minute, when the pressure was maintained at 300 lbs. per square inch. The pressure was maintained in the pipes by means of a clack fixed between the pump and the pressure-gauge.

The water came out of the jets in the shape of a very fine spray, and had the air-current been stronger, more satisfactory results would probably have been attained, as it must be patent to all that the greater the velocity at which the air travels, the longer will it retain the moisture imparted to it by the spray-jets. The air was travelling at the very low velocity of 1·93 feet per second, which was not sufficiently strong to retain the moisture for any lengthened period.

These experiments lead the writer to the opinion that the best way of using the spray-jets is to fix them singly in the intake airway, either at the side or from the roof, in such a position that the spray is ejected in the same direction as that in which the air-current is travelling. They should be erected at intervals along the roadway; but no regular distance can be laid down for all mines as to how far they should be apart, owing to the varying conditions of different mines, and indeed in various intake airways of the same mine.

The most economical way of obtaining the necessary pressure of water would be from the pit top or from the tubbing in the shaft; and as coal-dust is generally troublesome in workings which lie at a considerable depth, this method of dealing with it could come into operation with very little outlay or trouble where the depth is over 300 or 350 yards.

The pressure of water at the bottom of a shaft 350 yards deep—assuming the water came from the surface—would be 455·72 lbs. per square inch, a pressure quite sufficient for the successful working of spray-making jets. If the required pressure cannot be obtained naturally, it will be necessary to look to another source; and probably pumps would be required, working either by manual labour, steam, compressed air, or electricity.

It is a well-known fact that the temperature of the earth increases with depth, while at the same time the amount of moisture to be found decreases, and it is practically known that an increase of temperature in a mine does more damage to the roof and sides than if the temperature were materially decreased, because of the greater amount of moisture contained in warm air. Although the temperature during the experiments on the in-bye side of the spray-making jets was not appreciably decreased, yet it must be very much reduced when a series of jets is in operation, and the

higher the natural temperature of the mine the greater will be the useful effect of these spray-making jets.

Water in moderate or large quantities does not improve the roadways of a coal-mine with a floor of an argillaceous nature, but the writer thinks that the ejections from this spray-maker, when under considerable pressure, are so finely divided that no danger may be feared from that cause.

Mr. C. R. Barrett (Chester-le-Street) wrote that in a deep, dusty mine (of which he was the manager for a number of years) considerable expense and trouble were incurred in finding out the best method for laying the dust on the engine-planes and travelling-ways. At first, water tubs were run on the engine sett, with an iron pipe on the tub, full of small holes, and the water was turned on, on leaving the shaft, or at different stations along the plane, and sometimes when the full sett left the landing to come out-bye. In this way the engine-plane, 2½ miles long, got fairly well watered, but not more than about 1 foot on either side of the rails. It was then thought advisable to adopt some plan by which the sides and the top could be watered also. To do this, ½ inch pipes were attached to water-pipes, supplied from the tubbing in the shaft. At distances of about 30 yards, taps were placed with small holes, which made an excellent spray, but in roads of a large area it was found that the spray did not travel far enough to be of any practical use, and the road for 12 or 15 yards became very wet when the spray was on. Instead of these spray-taps, ordinary taps were afterwards used, fitted with screws, to which a hose 25 yards long could be attached. The taps were placed 50 yards apart. By this means the engine-planes were thoroughly watered, and when this was done, say once a week, the dust was always damp. In the travelling-way there was a range of 4 inch water-pipes, coming from an in-bye pump worked by compressed air. Taps were placed on to these pipes for the same purpose, and answered very well. If any member proposed to adopt this plan, the writer recommends him to put in pipes of not less than 2½ inches in diameter, as ½ inch pipes were found much too small, and there was not sufficient pressure at a distance from the shaft.

Mr. W. Galloway (Cardiff) wrote that, for the last seven or eight years, spray-producing jets, similar to those described in Mr. Hewitt's paper, have been in daily use in most of the important steam-coal collieries in South Wales. The water is brought down the shafts, distributed

in the main roadways by means of pipes, and ejected through spray-producers fixed on upright pipes placed at intervals of 20 or 30 yards apart. Mr. H. W. Martin, of Dowlais, invented some years ago, and has now in use a system of jets in which compressed air is employed in combination with water. The escaping air appears to pulverize the water, as it were, in a more effectual manner than the pressure of the water acting alone.

Mr. W. H. Routledge (Tredegar) wrote that any suggestion for rendering coal-dust innocuous will be welcomed by all who have charge of dusty pits. According to his ideas, coal-dust is dangerous, not only on account of the practice of shot-firing, where it is in vogue, but more especially where an accidental ignition of a small quantity of fire-damp may take place in any part of the workings. He is of opinion that with an initial flame, and a given quantity of coal-dust, an explosion may occur corresponding in magnitude with the accumulated dust in the roadways. The system described by Mr. Hewitt appears very simple, but the idea has been more elaborately carried out at the Dowlais collieries by Mr. H. W. Martin, who read a paper on his method to the South Wales Institute several years ago.* At the Dowlais collieries two lines of pipes are laid down along the roads, one for water, and the other for compressed air. These are connected at intervals by double nozzles having a small orifice. Issuing from the nozzles, the spray is carried along with the air-current, and thus ensures a fairly satisfactory humidity. The quantity of water necessary for saturation in this case will be less than by the plan Mr. Hewitt described. The table of observations given does not show the amount of saturation. He could not agree with the latter part of Mr. Hewitt's statement that "the water came out of the jets in the shape of a very fine spray, and had the air-current been stronger, more satisfactory results would probably have been attained, as it must be patent to all that the greater the velocity at which the air travels, the longer will it retain the moisture imparted to it by the spray-jets." His experience taught him that where the air-currents have so low a velocity as 120 feet per minute, and the volume of air is so small as 6,336·5 cubic feet per minute, the saturation of the air is easily attained without any specially constructed apparatus, and is often unintentionally accomplished in an expensive manner, and in a manner which is much to be deprecated. Where steam pipes are taken down the downcast pit to an underground engine, the heat from the pipes is often sufficient to raise the temperature a little above that normal to the mine, thus giving saturation

* *Trans. South Wales Inst.*, vol. xv., page 267.

to the intake for some distance from the downcast shaft. With high velocities, say over 600 feet per minute, and large volumes, say over 100,000 cubic feet per minute, difficulty arises in maintaining a regular saturation of the air. The constant variation in temperature of the air descending the downcast pit has such an effect, that what may be sufficient saturation one day may be insufficient the next. If Mr. Hewitt will kindly take the matter up more fully, and give a table showing the different temperatures of the air at surface, and the normal temperatures at intervals of an intake road, say 1,000 yards long, with the number of jets required to keep a certain volume of air at saturation or dew-point, it would be information of great service to mining engineers, as a fixed quantity of water from jets, or the hose system, is certainly far from satisfactory.

Mr. H. T. Wales (Cardiff) wrote that the best means of laying coal-dust had received serious attention in South Wales during the last ten years at collieries working the steam-coal seams, as these seams produce dust in large quantities and in a very finely divided state. The mines are fiery, and, as in many cases shot-firing is unavoidable, the presence of coal-dust forms an element of danger which has to be provided against. Water under various pressures has hitherto been the only method employed. At some collieries, until recently under the writer's management, water was conveyed from the surface in wrought-iron pipes 2 inches in diameter, and carried through the workings by pipes gradually diminishing to 1¼ inches in diameter. The head, due to the depth of the shaft, gave an average pressure of 600 lbs. per square inch. The distributing pipes were laid on the floor at the sides of the roads. At intervals of 40 yards sprays were fixed, consisting of wrought-iron pipes, ¼ inch in diameter and 18 inches high, fixed vertically in the main pipe, and reduced in diameter by means of a T-piece. Immediately above the T-piece an extra strong brass cock, ¼ inch in diameter, was fixed, by which the water could be turned off and on. The head of the spray pipe consisted of a brass nozzle screwed on to the wrought-iron pipe and pierced with a taper hole into which a brass-screw plug worked right through the pipe; the outside end of the plug was shaped so that it could be screwed in or out, as required by an ordinary key for locking safety-lamps. The inside end of the plug was tapered to fit the hole, which terminated in a needle-point (Figs. 1 and 2). It was found that the single hole became blocked and wore larger in time, and this spray was replaced by an ordinary rose made of brass, 1½ inches in diameter, pierced with a number of fine holes, and properly proportioned for withstanding the

pressure of water. Two ¼ inch bends were also fixed between the brass cock and the rose, and these allowed the rose to be turned in any direction so as to water the roof and sides where considerable quantities of dust are found to lodge. In places where shot-firing had to be carried on, the writer used india-rubber hose in 60 feet lengths, which were fastened to

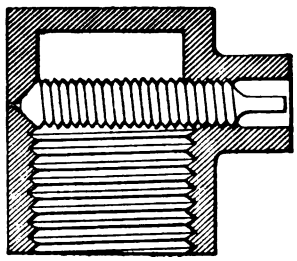


Fig. 1.

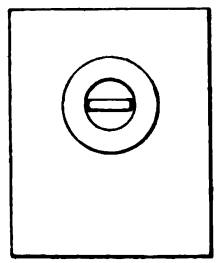


Fig. 2.

the spray pipes, and with which the floor, roof, and sides were thoroughly saturated before each shot was fired. A similar system to the above is in use at most of the South Wales steam collieries but in some cases a method, patented by Mr. H. W. Martin, of Dowlais, is carried out. In this arrangement a pipe conveying compressed air is connected to the spray pipe, and the water is blown out in the form of a fine mist.

Mr. H. B. Nash (Barnsley) proposed a vote of thanks to Mr. Hewitt for his paper.

Mr. Wragg seconded the motion, and hoped they would at the next meeting have a lengthy discussion upon the question of watering coal-dust, which was a subject which had caused him some difficulty.

The motion was agreed to.

Mr. E. M. Bainbridge (Sheffield) proposed a vote of thanks to the various firms who had thrown open their works and collieries for inspection by the members.

Mr. N. R. Griffiths (Wrexham) seconded the motion, which was carried unanimously.

Mr. T. Douglas (Darlington) proposed a vote of thanks to the local committee for their arrangements.

Mr. E. B. Wain (Stoke) seconded the motion, which was unanimously agreed to.

Mr. A. SOPWITH (Cannock) proposed a vote of thanks to the President for his services in the chair.

Mr. SPENCER seconded the motion, which was carried with acclamation.

The CHAIRMAN responded, and said if he had conducted the meeting to their satisfaction he had been amply repaid.

The meeting then terminated.

The members dined together in the evening at the Royal Hotel.

The following notes record some of the features of interest seen by visitors to collieries and works, which were, by kind permission of owners, open for inspection during the course of the Derby Meeting, on February 22nd and 23rd, 1893:—

SHIPLEY COLLIERIES.

At the WOODSIDE PIT, there are two winding shafts, each 7 feet in diameter, drawing upwards of 1,000 tons per day from the main soft coal, at a depth of 216 yards. The output was doubled by duplicating the vertical winding engine, by pulling tubs off both decks at once, and the introduction of extensive banking machinery.

The boilers, of Lancashire and egg-ended types, are fitted with the Perret system of forced draught, and fired with dust-coal carried by a conveyor from the shaking screen to the end of each boiler.

The ventilation is produced by a Rammell fan.

The underground haulage is on the side system.

At the COPPICE PIT, upwards of 1,100 tons are drawn per day from one shaft of 13 feet diameter. The seams worked are the deep hard (or potter's coal) at 204 yards and the main soft coal at 187 yards.

A single engine on the surface works bucket pumps and three-throw pumps delivering water from the deep hard coal to the surface, and also works about 4 miles of underground haulage of the under-rope type.

A sorting belt and shaking screen are in use; and a second belt and screen is in process of construction.

This colliery is ventilated by a Guibal fan, 30 feet in diameter and 10 feet wide.

There are three pumping plants. One erected in 1819 pumps from the bottom hard coal by two treble lifts; another of uncertain date

pumps from the top hard; and a plant is nearly completed, consisting of a compound surface condensing horizontal engine, with cylinders of 45 inches and 80 inches in diameter, and stroke of 10 feet, to work two 20 inches plungers at a depth of 240 yards, and two 9 inches plungers at 100 yards.

The new boilers are fired on the Perret system.

The manufacture of lime cartridges was inspected.

MIDLAND RAILWAY COMPANY'S LOCOMOTIVE WORKS, DERBY.

The ground area is now 80 acres, and covered area 12½ acres.

Number of men employed, nearly 4,000.

Stationary engines to drive machinery, 22. Horse-power of same, 2,400.

Number of new engines built yearly, 40. Number of engines rebuilt with new boilers, 120.

Number of engines dealt with yearly for heavy repairs, 750 to 800.

The general foundry turns out 120 tons weekly. Chair foundry, 300 tons.

The machine shop has over 400 machines.

The erecting shop will hold 108 engines.

Four running sheds stable 150 engines.

The total number of engines is 2,296.

Engine mileage is 56,646,625 per annum.

A test office deals with all forms of mechanical testing, and a laboratory with all kinds of chemical analysis.

The water-softening apparatus deals with 4,000,000 gallons per week, or 30,000 gallons per hour.

The gas works supplied 119,142,800 cubic feet last year.

Three mess-rooms, with cooks provided by the company, seat 1,500 men.

MIDLAND RAILWAY COMPANY'S CARRIAGE AND WAGON WORKS, DERBY.

The objects of interest seen *en route*, in going through the carriage and wagon works, which are designed and laid out for the construction and repairs of railway carriages and wagons, were:—(1) the system upon which the timber is dealt with on arrival; (2) its conversion and stowage

for seasoning; (3) the wood-working machinery for preparing timber; (4) the putting together of the different parts in the building of wagons; (5) the same for carriages; (6) the upholstering of the carriages; and (7) the painting of the carriages.

At the other side of the works, or the iron department, the visitors saw the system of receiving the bar iron, the foundries, forge, smithy, machine and fitting shop, spring-making, bolt and nut-making, and the operation of repairing carriages and wagons, etc.

The timber yard, sidings, etc., were shown *en route.*

The area of the ground occupied by the works is about 100 acres, about one-fourth of which is covered with shops. The number of men employed is 3,600.

MESSRS. BASS, RATCLIFFE, GRETTON, & CO., LIMITED, BURTON-ON-TRENT.

Messrs. Bass, Ratcliffe, Gretton, & Co., Limited, are the chief of twenty-eight firms of Burton brewers, who represent nearly one-tenth of the entire brewing trade of the United Kingdom. In the course of a brewing season the firm send out over 800,000 barrels, and receive into the works during that time raw material weighing 850,000 tons. In a year the firm pay the railway and canal companies and others upwards of £180,000. In the production of that quantity of beer, 250,000 quarters of malt are used, and 34,000 cwts. of hops. The land required for the production of the malt would be 67,000 acres, at 30 bushels of barley per acre. The quantity of coals used during the twelve months is 40,000 tons, exclusive of malting coal and coke, which amounts to 9,500 tons. The amount of malt-tax and licence-duty paid to the Government for the same period was £286,000. The amount of business done by the firm in one year is probably little less than £2,400,000.

There are three breweries—the new, the middle, and the old; a steam cooperage; hop and ale stores; and thirty-two maltings.

To the quality of its water Burton-on-Trent owes its eligibility as a beer-making centre. It stands in a basin surrounded by hills, which, on the west, largely contain marl and gypsum. The water from these hills, being impregnated with sulphate of lime, percolates into the basin, and is of great importance in brightening beers and saving the use of finings. No brewing water comes from the east. It is now necessary to bore for it to a depth of from 100 to 300 feet.

Explosion of malt-dust, which will occur occasionally in the Jacob ladder arrangement, is effectively provided against and rendered harmless by enclosing the ladder in a strong iron sheath carried above the building, so that the flame cannot spread laterally but is projected upwards into the air.

MESSRS. JOHN DAVIS AND SONS' WORKS, DERBY.

In the lamp factory many varieties of miners' safety lamps were seen in process of construction, one of the special features being the uniformity of size and the interchangeability of parts ensured by the use of standard screw-cutting tackle. The Wolstenholme safety-lamp cleaning machine was shown, comprising arrangements for unscrewing the ring holding the glass and gauze, for cleaning and polishing all parts of the lamp, and for re-screwing the ring into position.

In the scientific instrument department the visitors saw the manufacture of mining dials, theodolites, self-timing anemometers, levels, and other instruments of interest to mining engineers.

The electrical department comprises the manufacture of all appliances used in the installation of electric light and power plants, with their collateral electrical accessories, telephones, and electric signals, together with the appliances for shot-firing on either the high or low-tension principle.

There is a station at the works for the distribution of electric current to hotels, shops, offices, and private houses in the vicinity, which has been at work for over four years. The plant consists of an engine, dynamo, and battery of 60 accumulators, with the accompanying switches to regulate the supply of current to the various distributing cables, together with an automatic switch to disconnect the dynamo from the accumulators should the pressure of the former fall below that of the latter.

SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, FEBRUARY 2ND, 1893.

MR. W. F. CLARK, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

The following gentleman was elected :—

MEMBER—

Mr. H. S. MUNROE, Professor of Mining, School of Mines, Columbia College, New York, U.S.A.

REVISION OF RULES.

The SECRETARY explained the nature of the alteration of the Rules required by the Federated Institution of Mining Engineers, respecting the classification of Members.

Prof. R. H. SMITH read the following remarks on "Compressed Oxygen":—

COMPRESSED OXYGEN.

By Prof. R. H. SMITH.

For many years there have been various methods of manufacturing oxygen. The material out of which the oxygen was originally extracted was, in the first place, an expensive material, and in the second place, it was wholly used up in the processes to which it was subjected. The process which had now taken the place of those formerly in use was one by means of which oxygen was extracted from the air of the atmosphere, which was in fact an enormous reservoir of oxygen, and upon which they could draw to any extent they chose without payment.

In manufacturing oxygen from the air they first of all purified the air in lime-and-soda purifiers, and afterwards passed it through cylinders or retorts containing baryta, which were heated in a furnace. In the first stage of the process, during which the air-current passed into the retorts at 10 lbs. per square inch pressure, the inflowing air slightly lowered the baryta in temperature, and the baryta took up one atom of oxygen from the air. During the second stage the temperature rose somewhat because of the stoppage of the air-current, and the baryta gave out the oxygen under a vacuum of from 26 to 28 inches of mercury produced by an air-pump. The oxygen was delivered into a holder like ordinary gas. For commercial purposes it was usually supplied under a pressure of nearly 1 ton per square inch. If it was to be used on a large scale for any special purpose, the best way was simply to deliver it into a holder, whence it was drawn off when required. But for general purposes, where it was used in small quantities, it could not be made so cheaply as on the large scale. The gas was therefore sold from the oxygen-making works, and sent considerable distances at cheap rates. Oxygen was a bulky material, and therefore had to be compressed many times before it could be distributed. For this purpose it was drawn from the gas-holders and pumped into cylinders at a pressure of 1,800 lbs. per square inch, and in that condition could be safely and economically carried over long distances.

Mr. KNOWLES observed that at Saltley, they were filling oxygen gas into cylinders under pressure for small users. For large users the system of distribution at Saltley would be quite out of the question. The cost of this gas was somewhat heavy, owing to its being compressed into the cylinders. At gasworks, and where very large quantities were used, the cost was under 2s. 6d. per 1,000 cubic feet, but at the Saltley works the cost, including the compressing into the cylinders and production of the purest gas that could be made, was much higher, being about 12s. 6d. per 1,000 cubic feet. The first application of oxygen was to take advantage of the very high temperature of flame produced. Oxygen burnt with coal-gas produced the hottest known flame. This intense heat was utilized in the limelight, which was merely a piece of lime held in the flame. Its effects were easily seen with a piece of iron or brass, which was speedily melted by the flame. The flame indeed would melt almost anything introduced into it. The flame could be used for brazing and could be advantageously employed in glass welding. It was used very successfully in making large glass tanks from sheets of glass; the sheets were placed together in the form of tanks and the edges welded together. This could not be done without the aid of oxygen, although it did not require pure oxygen. It was being very largely used and was very beneficial in lung and heart complaints. It might be used with advantage in mines in cases of suffocation from choke-damp, etc. Oxygen was also used for the purification of coal-gas, and in the manufacture of sulphuric anhydride and various chemicals, of aniline dyes, and for the oxidation of oils. It was used in the manufacture of the oxy-oil-gas for increasing the illuminating power of coal-gas.

Prof. SMITH said he could give personal testimony to the utility of the use of oxygen for lung disease. Some months ago he was confined in the house for three or four weeks, and used oxygen with great benefit. An excess, however, of oxygen was just as bad as none at all. He used it in various forms, and he found that it was most acceptable if the oxygen was allowed to escape very gently and at some distance from the face. Of course, in cases of suffocation they would need to use it in a more vigorous manner. He might mention also the effect of oxygen upon human excreta, which was not generally a dangerous substance, but in hospitals it was sometimes a dangerous material. Now, the application of oxygen is of great service; for the moment oxygen was allowed to play over the freshly evacuated excreta, complete disinfection took place in a surprisingly instantaneous fashion. He might add that he had laid the matter

of the use of oxygen in fighting cholera before the Local Government Board, who were at present considering the possible utility of the application of oxygen in connexion with any recurrence of cholera.

On the motion of the PRESIDENT, seconded by Mr. FARNWORTH, a vote of thanks was given to Prof. Smith and Mr. Knowles.

The meeting then terminated.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

SPECIAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,

JANUARY 30TH, 1893.

MR. WM. HEATH, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the previous General Meeting, which were confirmed.

The following gentleman, having been previously nominated, was elected :—

ORDINARY MEMBER—

Mr. JOSEPH COLIN SILVESTER, Electrical Engineer, Castle Hill Works, Newcastle-under-Lyme, Staffordshire.

The officers for the ensuing year were then nominated.

Mr. R. H. WYNNE read the following supplementary notes on "Coal: its Varieties and Application to Manufactures and the Arts":—

COAL: ITS VARIETIES AND APPLICATION TO MANUFACTURES AND THE ARTS.*

By RICHARD H. WYNNE.

Supplementary Notes.

In the course of a recent discussion on a paper read before the members of this Institute, entitled "Coal: its Varieties and Application to Manufactures and the Arts," several interesting points were raised, particularly one as to the information to be obtained from chemical analysis in showing the difference between caking and non-caking coal; and the discussion† was adjourned with the understanding that a supplementary paper would be prepared with the object of further elucidating some of the points raised. For the purpose of carrying out that intention the following brief paper is now brought under the notice of the Institute with the hope that the information contained therein, together with the discussion upon it, may prove to be of some interest to the members in considering the questions referred to on the previous occasion.

As described in the previous paper the different varieties of coal may be arranged in five principal classes:—

1. Anthracite.
2. Steam, free burning or dry coal.
3. Bituminous or caking coal.
4. Cannel (including the Boghead variety, sometimes called torbanite).
5. Lignite or brown coal.

The order of classification is arranged with reference to the specific gravity and quantity of carbon in each variety, the first and last in the list representing respectively the greatest and least density, and highest and lowest percentage of carbon; but in these notes it will scarcely be necessary to do more than refer to two kinds of this description of fuel, *i.e.*, free burning or dry coal, and bituminous or caking coal.

It has already been noticed that considerable difficulty exists in determining, with any approach to scientific exactness, a precise definition of

* *Trans. Fed. Inst.*, vol iii., page 234.

† *Ibid.*, vol. iv., page 307.

the minerals classed as coal; in the same way, a similar difficulty prevails in discovering absolute essential differences, by chemical analysis, between caking and non-caking coal. The property of producing a considerable volume of illuminating gas with other solid and gaseous products is, as a general rule, associated with coals of a bituminous or caking character, but this gas-producing quality is one of degree only; for example, coal of a non-caking description is extensively used in the smelting of iron, a large volume of gas being given off and utilized for heating the blast and raising steam, also in some cases solid residuals are extracted from the so-called waste gases, thus showing that the flaming and gas-producing quality is not a reliable criterion of the caking or non-caking condition of the coal.

When enquiring as to the information obtainable from chemical analysis, it is useful and interesting to refer to the work on fuel published some thirty years ago, by the late Dr. John Percy, who in discussing the question of caking and non-caking coals divided these varieties into three classes for the purpose of discovering the relation between the volatile products and the property of caking, viz.:—

I. Non-caking coals, approximating to anthracite in ultimate composition.

II. Caking coals.

III. Non-caking coals, further removed from anthracite in composition than class II.

This division is followed by a number of analyses of coals belonging to each of these classes, as follows:—

Divisions	I.		II.			III.			
No. of Analysis ..	1.	2.	3.	4.	5.	6.	7.	8.	9.
Carbon ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Hydrogen ...	4·75	4·45	5·49	5·85	5·91	6·34	6·12	6·44	5·99
Oxygen and Nitrogen ...	5·28	7·36	10·86	14·32	18·07	21·6	22·23	22·55	23·42

This table is erroneous to the extent of the nitrogen being regarded as constant and as not affecting the result. From these analyses the proportion of disposable hydrogen (considered to be the measure of fitness for the production of coal-gas) in each sample is calculated with the following result:—

Divisions	I.		II.			III.			
No. of Analysis ..	1.	2.	3.	4.	5.	6.	7.	8.	9.
Hydrogen ...	4·09	3·53	4·13	4·04	3·65	3·70	3·47	3·22	3·06

Dr. Percy then remarks: "Hence it appears that there is no essential connexion between the proportion of disposable hydrogen and the property of caking, for it is nearly identical in Nos. 1 and 3 and in Nos. 5 and 6, which are non-caking and caking respectively." Another writer quoted by Dr. Percy says: "Caking and non-caking coals may have the same ultimate composition, and the quality of caking may depend on the proximate constitution, that is, on the manner in which the elements are combined."

Several writers express the opinion that a pulping process is evident in the production of coal, owing to the intimate mixture of the mineral matter, the ash in the majority of cases not being recognizable before burning. Apparently on this hypothesis, together with the change which frequently takes place in organic matter, the coal of the Saarbrück coal-field has been divided by Dr. Schondorff into three divisions, classified according to their caking quality and their probable original condition in the vegetable kingdom:—

(*a*) Fibrous coal derived from unaltered cellulose or woody fibre of plants, producing, when submitted to a process of coking, charcoal or non-coherent coke.

(*b*) Dull or striped coal resulting from natural gum or dextrine or produced from the transformation of cellulose and starch, which yields an inferior coke.

(*c*) Glance or bright coal produced from insoluble mucilage due to the maceration of plants in water, and yielding, under similar conditions, a strong hard coke.

Another German chemist has experimented upon several isomeric hydrocarbons having the same ultimate composition, $C_6H_{10}O_5$, which when submitted to coking gave the following results:—

Cellulose or Swedish filter-paper gave 6·74 per cent. of non-coherent coke.

Gum arabic left 20·42 per cent. of hard dull coke resembling that from imperfectly-coking gas coal.

Starch produced 11·30 per cent. of vesicular coke similar to that of a strong coking coal.

This latter result appears in some measure to agree with the observations of Dr. Schondorff; but it seems we are still left very much in the dark on the subject of caking and non-caking coal, so far as knowledge is to be derived from chemical analysis. The best source of information available is, without doubt, practical experience and close observation of, and experiments with, the various descriptions of coal under different circumstances, whether for illuminating gas, manufacturing, household, or coking purposes, and in the latter case by washing, disintegrating, or mixing together various qualities of small coal.

Coke, the carbonaceous residue from coal subjected to a strong red heat, is essentially carbon or so-called fixed carbon together with the incombustible matter or ash contained in the coal; the quality, generally speaking, appears to be derived from differences in the power of cohesion of the individual particles. The quality may be attributed to the original constitution of the coal itself, as shown by Dr. Schondorff, or to the mode of preparation. Coke produced at a low red heat, as in gas making, is of a dull black colour and a loose spongy texture; while that prepared for manufacturing purposes, or for making iron or steel, is submitted to a high temperature with long-continued heat and is produced in a hard and dense form with considerable metallic lustre. There are great differences in the time required to produce coke from different varieties of coking coals; for instance, it is said that the coke at Ebbw Vale, Monmouthshire, is made in twenty-four hours in Coppée ovens, while other coals require a much longer time to carbonize in the same description of coke-oven.

On a former occasion some discussion took place on the difference in the properties, as regards the bituminous character, of the coal in different localities; further observation has shown that not only do the lowest coals of the North Staffordshire field become changed as they pass from the eastern to the western boundary but also the upper seams, though perhaps not to the same extent. For example, the Moss coal on the eastern and south-eastern sides of the district is free burning in character and on the western side, where it is known as the Single Four-feet, it is of a bituminous description, but not in so marked a degree as in the seams lower in the series. This circumstance is clearly seen on observing its behaviour when used for household purposes, and is further exemplified when it is submitted to coking after disintegration and washing, but the coke is somewhat friable when compared with that made from the lower seams.

There are some instructive facts to be gathered from descriptions of the Continental coal-fields, as to changes from caking to non-caking coals.

It is said that near Mons and Liége (Belgium), the upper series of coals are of a fat and caking character and the lower ones lean and anthracitic. At Saarbrück (Prussia) the reverse is the case, with a well-marked horizon of prominent seams. At Anzin (France) a large fault brings the lower and dry coals opposite the higher and coking seams.

In considering the apparent anomalies arising in discussing the question of caking and non-caking coals, we are much indebted to Mr. M. Walton Brown for his able and concise notes written to record some of the features of interest observed during an excursion to the Pas de Calais coal-field of France.* In these notes it is pointed out that at the Bethune colliery there is a large east-and-west fault of about 400 yards, dividing the royalty into two districts. On the south side of the fault the coals contain 28 to 30 per cent. of volatile matter down to a depth of 300 yards, while on the north side in the lowest measures, compared with the south side, the percentage varies from 12 to 18 within the same depth of 300 yards; it is also observed that the percentage of volatile matter diminished with the depth and thickness of the seams.

The preceding brief supplementary notes will in some measure carry out the proposed endeavour to elucidate some of the peculiarities and characteristics of the contents of our coal-fields. It is hoped that the result may prove acceptable to the members of the Institute, and that the discussion, which will probably ensue on a future occasion, will lead to further investigations and enquiries based upon observations, which after all may be considered to be the best and most reliable method of obtaining accurate information of permanent value.

DISCUSSION UPON MR. E. B. WAIN'S PAPER ON "THE LONGWALL METHOD OF WORKING AS APPLIED TO SEAMS OF MODERATE INCLINATION IN NORTH STAFFORDSHIRE."†

Mr. E. B. Wain said that in writing the paper which was to be discussed that day, he did so hoping that it might be one of a series dealing in a practical manner with the details of working adopted in the various districts represented by the Federated Institution. If members in other districts would take up the matter as regarded their own methods of

* *Trans. Fed. Inst.*, vol. iii., pages 1016 to 1032.

† *Ibid.*, vol. iv., page 24.

working, he felt sure that much valuable information might be accumulated in the Transactions. Looking through Transactions of the various mining institutes, it was surprising to find how little attention had been given, in the various papers contributed, to the most important of all colliery operations, that of the actual coal-getting. Paper after paper could be found giving every imaginable detail as regarded haulage, ventilation, lighting, screening, and many other matters, all no doubt of considerable importance, but after all, only accessory to the real work of winning and working the mineral. No one could deny that this was a matter of supreme importance; for, no matter how perfect the hauling, ventilating, banking, and screening, and other incidental arrangements might be, the advantages gained by such perfection would be of little real service unless the workings were laid out so as to maintain the roadways in the best possible condition at the lowest possible cost; and, what was of even still more importance, unless the mineral was wrought and was extracted with the least possible labour in the most marketable condition, and with the least risk to life and property. With the Federated Institution which now represented, or shortly would represent, every mining district of the United Kingdom, there were exceptional opportunities of collecting information of this kind. It was therefore his intention in writing the paper now placed before the meeting to offer his small contribution to what he considered to be a work of considerable importance, rather than to bring forward any novel point in mining engineering; and it was probable that this might appear tedious or even commonplace matter, especially to those who were more or less familiar with workings carried out on similar lines. He hoped, however, that it might prove to be of some interest to those fellow-members of the Federated Institution who had not the same opportunities of seeing the system of working in operation, just as he had found the paper by Mr. Craig, read at the same meeting, on "The Opening Out and Working of the Rearer Coals of North Staffordshire," of special interest, as dealing with the details of a method of working which he had never had an opportunity of seeing in operation. He had little to add to what had been said in the paper, which was a simple record of actual working, and in which any theories raised were based on personal observation in the routine of daily work, but if there were any points which called for fuller explanation he would be pleased to give it. There was, however, one special point which called for further explanation, and that was as regarded the line of the main break from the lower side of the working, as shown in Figs. 2 and 5, Plates I. and II.* This was shown as making

* *Trans. Fed. Inst.*, vol. iv., page 34.

an acute angle of about 50 degs. with the line of dip. It was not intended that this should be taken as the actual final line of fracture, but as showing the last main break which could be observed in the earlier stages of the work. There was no doubt in his mind that eventually the main break took a line parallel, or nearly so, to the main break from the working-face on the rise. In fact, he had had several recent opportunities of accurately observing the actual line of fracture to the surface. In one noteworthy instance (Fig. 10), workings of a limited area in a seam about 6 feet thick, at a depth of 210 yards from the surface, were clearly shown to have broken through the whole of the overlying strata from the lower side of the coal, worked in a line as nearly as possible at right angles to the dip of the mine. There was one other point which perhaps needed to be more strongly brought out, and that was the necessity for the packing being thoroughly well done, as the whole success of the system depended on this. Many workmen appeared to think that any sort of a heap of dirt thrown together with a shovel and loosely walled round was good enough, but by pointing out the important part which the packing took in the work he had endeavoured to combat this fallacy. Every section of the packing should be uniformly built, so that it would take its proper part of the pressure from the sinking roof. It was just as important that this should be done, as that the foundations of a massive building should be well laid, perhaps even more so, for in the latter case the pressure was uniformly distributed; but in the case of underground workings of this class the strains fall obliquely and often violently. The cross walls in the level side packs were found to be a great source of strength, and should on no account be omitted.

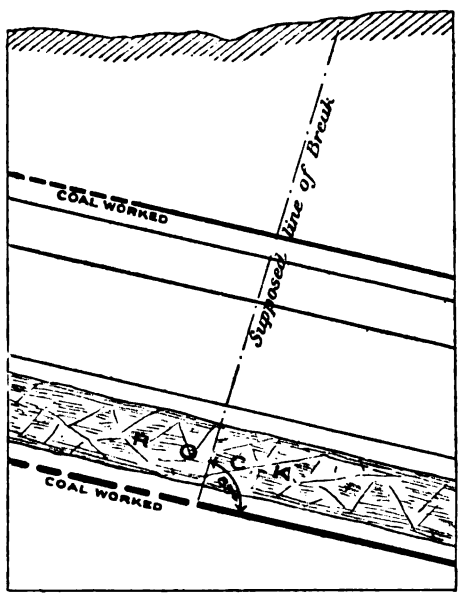


Fig. 10.

Mr. H. R. MAKEPEACE said he did not think it was possible to go into the discussion of Mr. Wain's paper further that day. Mr. Wain had added a few supplementary remarks to it, and in doing so he had alluded to one point that he (Mr. Makepeace) was rather desirous of speaking upon and emphasizing: that was, as to the importance of keeping up all packs and buildings in the longwall places. There was a considerable amount of longwall and modified longwall in this district, and he had almost daily opportunities of seeing in various colliery workings how it was carried on. He found great differences in the way in which the pack walls were put in. Almost daily he saw the importance of putting in the pack walls thoroughly and more systematically. It was a fact that at a great many collieries they heaped up the dirt and closed it up with a loose rubble wall, and thought that was sufficient to form a pack wall. In some cases when he went to a colliery he found part of the place fallen in. He had started to go to the working-face, and had had to go down a jig and up the next jig to get round to where he wanted to go, because there was a fall. Timbering also should be done properly, regularly, and systematically. It was notable that Mr. Wain had drawn out a scheme for timbering, regulating the distances at which the timbers must be set. They must not be set out any wider than a given distance; if necessary, closer; but no greater space must be allowed between the timbers than was stated in the printed instructions, posted up at the colliery. About eleven years ago, when managing some collieries in Scotland, he (Mr. Makepeace) drew up a similar scheme for a systematic method of timbering in the different seams under his charge. Whether the roof in the roads was good or bad, the timbers had to be placed at stated distances, and where the roof was very bad timber would be put closer. When the system got to work he found there was a saving of timber and a saving of cost in every way. There were less falls, and more of the timber, when it was drawn, could be used over again. This was much better than waiting till the road was broken down. He did not think there were many longwall workings in this district where the timbering was set in this systematic way. Generally, they were set in rows, but in some places they were diagonal and triangular, and all sorts of distances apart. He (Mr. Makepeace) regarded Mr Wain's paper as an extremely valuable one.

On the motion of Mr. J. STRICK, seconded by Mr. MAKEPEACE, a vote of thanks was accorded to Mr. Wynne and Mr. Wain for their papers.

REVISION OF RULES.

Mr. E. B. WAIN moved that the rules be altered, so that the Annual General Meeting shall be held in October instead of February; and that the financial year shall end at the same time as the financial year of the Federated Institution of Mining Engineers.

Mr. J. RICHARD HAINES seconded the motion, which was carried unanimously.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,

FEBRUARY 27TH, 1893.

MR. WILLIAM HEATH, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentleman was elected:—

ORDINARY MEMBER—

Mr. J. COLIN SILVESTER, Electrical Engineer, Castle Hill Foundry, Newcastle-under-Lymè.

REVISION OF RULES.

The PRESIDENT moved the confirmation of the alteration of rules to enable the officers appointed that day to remain in office until July, 1894.

This was seconded by Mr. E. B. WAIN, and carried unanimously.

ANNUAL REPORT OF THE COUNCIL FOR 1892.

The Council are pleased to report the continued success of the Institute, which, this year, attains its majority.

Since its inauguration papers relating to mining have been read upon many special subjects, including boring, sinking, blasting, boilers, ventilation, and haulage. These are recorded in the eleven volumes that have been printed and issued to the members.

Shortly a brief index of the volumes will be issued as an Appendix to Vol. XI., and those members who do not possess the earlier parts of the Transactions may purchase the same at a nominal price.

The numbers on the register are as follows:—

Life Member	1
Honorary Members	7
Ordinary Members	174
Non-Federated Members	13
Students	19
	214

As compared with 222 last year. This decrease is chiefly due to the removal of names from our list, who, through the Federated Institution of Mining Engineers, are members of other local institutes.

Death has removed three members from the list—Messrs. Clemenson, Oakes, and Challinor, the latter by an accident, the news of which was received by all with great regret; and we express our sympathy and condolence with the family of our deceased and respected colleagues.

Papers have been contributed during the year by Messrs. W. N. Atkinson, Boby, Taylor, Tonge, E. B. Wain, W. Holt Wain, and R. H. Wynne, upon interesting subjects.

We hope that the resolution to join the Federated Institution of Mining Engineers has been approved by the members generally; and we here call attention to the numerous and various papers in these Transactions, which comprise the following:—

Mine haulage	5	papers.
Mechanical engineering	7	"
Electricity as applied to mining operations	8	"
The use of explosives	7	"
Mine ventilation	5	"
Geological	18	"
General subjects	25	"

The foregoing list of papers clearly shows the benefits received by those members who have joined the Federated Institution of Mining Engineers.

In September last the Annual General Meeting of the Federated Institution of Mining Engineers was held in this district, and papers on local coal-working were contributed by Messrs. E. Craig and E. B. Wain, and an address upon the manufacture of china and earthenware by Mr. W. Burton. Excursions were made to various works and collieries, and judging from their remarks, the visitors thoroughly appreciated their visit to this district.

Mr. B. WOODWORTH moved the adoption of the twenty-first Annual Report of the Council, and explained that the financial statement had been deferred until July, when the financial year would in future terminate, so as to accord with the closing of the year of the Federated Institution of Mining Engineers.

Mr. F. RIGBY seconded the motion, and it was carried unanimously.

ELECTION OF OFFICERS.

The Scrutineers reported the following appointments:—

PRESIDENT.

ROBERT H. COLE, Esq., Endon, Stoke-upon-Trent.

VICE-PRESIDENTS.

W. N. ATKINSON, Esq., Newcastle-under-Lyme.
JOHN STRICK, Esq., Bar Hill, Madeley.
EDWARD B. WAIN, Esq., Whitfield Collieries, Norton-le-Moors, Stoke-upon-Trent.

COUNCIL.

THOMAS ASHWORTH, Esq., Pratt Street, Fenton, Stoke-upon-Trent.
WILLIAM BRIDGETT, Esq., Bucknall, Stoke-upon-Trent.
JAMES C. CADMAN, Esq., Silverdale Collieries, Newcastle-under-Lyme.
WILLIAM HEATH, Esq., Sneyd House, Burslem, Stoke-upon-Trent.
HUGH R. MAKEPEACE, Esq., Newcastle-under-Lyme.
GEO. A. MITCHESON, Esq., Market Place, Longton.
JOHN NEWTON, Esq., Longport, Stoke-upon-Trent.
FRANK RIGBY, Esq., Alsager, Cheshire.
JOEL SETTLE, Esq., Madeley Coal and Iron Co., Newcastle-under-Lyme.
FREDERIC SILVESTER, Esq., Newcastle-under-Lyme.
BENJAMIN D. VIGGARS, Esq., Hope Cottage, Downing Street, Silverdale.
BENJAMIN WOODWORTH, Esq., Heron Cross, Fenton, Stoke-upon-Trent.

TREASURER.

JAMES G. BAKEWELL, Esq., Newcastle-under-Lyme.

SECRETARY.

J. RICHARD HAINES, Esq., Adderley Green Collieries, Stoke-upon-Trent.

The RETIRING PRESIDENT then introduced Mr. R. H. Cole as his successor.

Mr. COLE, having taken the chair, delivered the following address:—

PRESIDENTIAL ADDRESS.

By Mr. R. H. COLE.

The choice of a subject upon which to address you to-day has given me a good deal of thought, but when I found this is the twenty-first annual meeting of the Institute, and that we may therefore congratulate ourselves upon our association having attained its majority, I thought it might serve some useful purpose if we took counsel together on a few points which, I think we shall agree, bear upon the welfare of the Institute itself, and see whether any modifications, if only slight in themselves, may help us to attain at all events something nearer the object which a Mining Institute is founded to secure.

I assume that the general principles are to promote the advancement of mining science in all its various branches, so as to assist members of the Institute, and more especially its active members, in obtaining the most economical and the safest results from the opening and development of mines. On this, I have no doubt, we are all agreed, but we may differ to some extent as to the best means to be adopted in securing these advantages. One thing, however, is certain, that unless a steady, constant, and increasing ratio of progression is maintained, any Institute, no matter how strong it may be numerically, will soon lose touch with its members, and so by natural consequence of the principal objects for which it was formed, its capabilities for usefulness will be crippled, and it may become of little more than nominal value in the district where it ought and was intended to be most beneficial. It may be that all, or very nearly all, who are eligible as Ordinary or as Honorary Members are on the books of the association and that the subscriptions are paid with fair punctuality; but, gentlemen, if the functions of a Mining Institute are such as we have agreed they are, the duties of members (I mean, of course, the bulk of those who form the working body of the Institute,) surely do not begin and end with the simple payment of subscriptions. What is absolutely essential to the growth of vigorous life in an association like this is the members' presence at the meetings as well as their financial support, because both are equally essential to the successful working of a Mining Institute, and one form of participation should be as regular and as unstinted as the other.

In this respect I would draw your attention to one marked feature in Mining Institutes generally, and that is the active interest now being taken in their proceedings by H.M. Inspectors of Mines. In this district we have for some years been specially favoured in that way. As we are almost all aware, Mr. Sawyer, while he remained in this district, took a very active part in our meetings in diffusing the best of his knowledge and experience amongst us and in eliciting the opinions of members in his researches, and I am sure you will fully endorse the opinion that this Institute owes much to Mr. Sawyer for the information gained from him and always most willingly rendered, and for the high general tone he infused into the discussions which he originated or in which he took part. At the present time our friend Mr. Atkinson, as you heard at the opening of these proceedings, has been unanimously elected a Vice-President, and his colleague, Mr. Makepeace, again a member of the Council of the Institute, and although the statistics of attendances of members of Council are not published, it is no breach of confidence to say that their punctuality and regularity of attendance will compare most favourably with those of almost any other member, and their active interest in everything connected with the welfare of the Institute is being constantly shown. Why I name those facts—for facts they are—is that they appear to form a complete answer to the remarks of critics who say Mining Institutes sometimes fail to come up to the expectations of their promoters and supporters, because it is not possible to believe that these gentlemen at least would be content to attend meetings constantly, prepare and read papers on mining subjects, and take an active part in the discussions unless they saw clearly that great benefit to the mining district was to be derived from them in respect to the economical and safe working of mines.

Having briefly considered the advantages to be derived from joining and attending a Mining Institute I should like to consider with you for a few moments any improvements that may suggest themselves for securing those advantages. The reading of papers on different mining subjects and the subsequent discussions thereon are generally the acknowledged channels through which information is best disseminated, the choice of subjects being a purely voluntary matter. Now I venture to submit that it would be beneficial if this rule were modified, and that the Council of the Institute—to whom we must invariably look for guidance in such matters—should decide upon certain subjects for consideration, that they should determine who is best qualified to throw the most light on those subjects, and that whoever their choice may fall upon be asked to contribute papers at the earliest opportunity, and that at least one or two other members in

each case be asked to prepare themselves for opening the discussion that will follow. These discussions are among the most interesting features of the proceedings, and I believe it to be almost as essential to prepare to discuss a paper as it is to write one. I do not think this method of procedure would tend to discourage or to weaken voluntary effort in our proceedings, but rather to strengthen and develop it, by ensuring wider interest at each successive meeting. And with regard to that interest I think it will be agreed all round that the discussions should follow immediately upon the reading of any paper, *i.e.*, at the very next meeting, and to help us in this respect we should have to ask as much indulgence and consideration as possible from the press. The papers should be reported as fully as possible, so that any members who may have been chosen to initiate or continue a discussion may have sufficient material at hand almost at once to enable them to supplement or controvert any conclusions at which the writers of papers may have arrived. Besides, gentlemen, pens, ink, paper, and postage are not such costly matters now that a few special questions cannot be asked and answered to clear up any points between the parties which may not be sufficiently explicit in the condensed report. I think in this way, by dealing with each approved subject promptly, we are more likely to obtain reliable information and in a more condensed form than we can do otherwise. Our Transactions are most useful as reference books, but I venture to think they do not reach the members' hands quickly enough to found a discussion upon if that discussion is to be of the requisite searching character, and promptness adds much to the vigour of any discussion.

As to choice of subjects, it is doubtful whether any mining district in the kingdom presents more variety than does our own district of North Staffordshire, when we consider that the mines lying under a comparatively small surface-area comprise in the centre of the coal-field, and at a depth of 1,100 or 1,200 yards, some ten workable seams of ironstone with an aggregate thickness of probably 25 feet, and twenty-eight or twenty-nine workable seams of coal with a probable aggregate thickness of nearly 125 feet, to say nothing of the capabilities for profitable working of many of the intervening seams of marl, which yield a large tonnage in all parts of the district. That some of these seams vary in characteristics most materially in different parts of the district—that the natural inclination of the seams vary to such an extent that occasionally in the same leasehold, seams of coal will vary in inclination from nearly horizontal to perfectly vertical—surely, gentlemen, considering all this, we need not go far for subjects of great interest to us all. I feel convinced that if the

Council will test the proposal by making a direct appeal to the members of the Institute for papers on specific subjects, that appeal will meet with a hearty response.

Now, gentlemen, I feel there is at least an explanation due to you in respect of the shortness of this address, which contains nothing but what we are all conversant with, and nothing whatever original, but such was my intention throughout. The object I have had in view has not been to attempt anything original, even if the requisite qualifications had been present, which they are not. It may be a very easy or a very difficult matter—it has not been tried here—to draw up a paper bristling with statistics and containing bundles of figures of most fascinating proportions; and there is probably no business in the world that offers such tempting inducements in that respect as does mining, because, given anything like a fair extent of mineral area and the numbers and thickness of seams, like what we have in North Staffordshire, millions of tons and their attendant thousands of other figures crowd in quite naturally and, indeed, in greater abundance than a writer well knows what to do with. But it could not serve any useful purpose to use such figures here to-day; what is desired is, if possible—and it most probably is possible—to try to awaken a deeper interest in the members of the Institute as to their individual responsibility in its welfare, and it may be to influence them to consider that when a subscription is paid it is to be looked upon only in the light of a deposit, showing a member's intention to complete the bargain in full by using his best efforts for the welfare of the Institute, and so to quicken its life and assist in its more complete development.

Mr. W. Heath moved a vote of thanks to the President for his address, which he said ought to stimulate them all to renewed and increased efforts in the promotion of the interests of the Institute.

Mr. J. R. Haines (the Secretary), who seconded the resolution, said there were many advantages in joining the Federation, and the one disadvantage was the delay in publishing the Transactions. The papers and discussions of five Institutes had to be revised and corrected, but perhaps when they got more fully into work the delay would be obviated.

The motion was carried unanimously.

Mr. J. Strick proposed a vote of thanks to Mr. W. Heath for his past services as President.

This was seconded by Mr. R. H. Wynne, supported by the President, and carried very heartily.

DISCUSSION UPON MR. E. B. WAIN'S PAPER ON "THE LONGWALL METHOD OF WORKING AS APPLIED TO SEAMS OF MODERATE INCLINATION IN NORTH STAFFORDSHIRE." *

Mr. J. R. HAINES, referring to Mr. E. B. Wain's supplementary remarks at the previous meeting,† said for some considerable time past in North Staffordshire, the question of subsidence and draw had been moot points. There were one or two points with respect to which he should like further explanation. The first was as to the order in which the workings were carried on. The second was as to the subsidence or dislocation in the four seams overlying the coal that was worked.

Mr. E. B. WAIN said no coal had been worked above or near to the one from which he had traced a fracture to the surface. The nearest workings were in an upper seam (100 yards above and 60 or 70 yards to the rise) which had been worked seventeen or eighteen years ago. He was not able to say definitely whether there was any trace of subsidence from the other seams. From that point, about 100 yards from the surface down to the datum-line of the fifth seam, there had been nothing worked, and, further, there was a band of rock, 30 yards thick, including the Ten-feet rock. The vertical depth of the crut was 220 yards. He had been able since he read his paper to trace similar subsidences in even deeper seams, and the line of inclination of the break appeared to be as nearly as possible at right angles to the dip of the mine in every case.

Mr. G. A. MITCHESON asked what was the nature of the overlying rock?

Mr. WAIN replied that they were the rocks between the Ten-feet coal and the Mossfield coal.

Mr. MITCHESON asked if the Yard-coal rock was strong there?

Mr. WAIN replied not so strong as in other parts of the district. It was semi-rock, and the Ten-feet rock was particularly strong at that point.

Mr. MITCHESON wished to know if Mr. Wain had noticed any other breaks before that one on the crut side, or whether it showed a break right through at once.

Mr. WAIN answered that the break ran parallel to the line of coal-working; assuming that this line represented the limit of coal worked on the plan, the break ran as nearly as possible parallel, but at a distance of 50 yards, and as the workings extended the break also extended. The break was so marked that the farmers were afraid that their cattle would

* *Trans. Fed. Inst.*, vol. iv., page 24. † *Ibid.*, vol. iv., page 514.

fall into it. He had no other case where it was possible to see the line of break so clearly, but there was nothing worked above or below it, and they were able to locate it exactly.

Mr. HAINES asked if the seams were worked from the dip to the rise?

Mr. WAIN—Yes.

Mr. R. C. CLIVE observed that Mr. Mitcheson asked if there were any other breaks noticed by Mr. Wain—whether there were any smaller breaks?

Mr. WAIN thought Mr. Haines had given an answer to that question. The workings had been driven from dip to rise, and not downwards, so that the first indications would be found where the break took place from the solid on the dip side.

Mr. MITCHESON asked whether in working from dip to rise Mr. Wain had noticed any breaks in the more vertical position?

Mr. WAIN referred to Figs. 2 and 5, Plates I. and II.,* illustrating the position of the first break, and said those lines were at about 35 degs. to 65 degs. from the horizontal, and these were the lines observed in the actual working. With regard to subsequent breaks no settlement had taken place, and they could not be traced with the same accuracy.

Mr. MITCHESON enquired whether any of the breaks had made their appearance on the surface before anything was noticed in the mine?

Mr. WAIN thought not.

Mr. MITCHESON thought that the nature of the overlying strata had a great deal to do with the line of break.

Mr. WAIN replied that he used to think so; but on going into the question very carefully, measuring each district and the actual line of break, he found in almost every case that the line of break was the same, although the roof varied from a soft bind, almost fireclay, to rock. The roofs were the Ten-feet and Bowling Alley, and he was able to trace the least fracture with the greatest accuracy. The lines of fracture were practically parallel in all the seams.

Mr. HAINES said he did not think they would get a fracture in marls, it would be a subsidence, and the subsidence in all probability would not be perceptible without taking the levels.

Mr. MITCHESON thought, whether it was a fracture or a subsidence, it was pretty much the same. If a seam was worked to the rise and the workings ceased at a definite point, would there not be subsidence formed where the goaf ended?

Mr. HAINES—Yes, but not to such an extent as to the dip.

The PRESIDENT asked if that would not depend very much on the angle?

* *Trans. Fed. Inst.* vol. iv., page 34.

Mr. HAINES replied that the roof overlying the seam doubtless had an effect upon the results produced.

Mr. A. M. HENSHAW said the subsidence was shown on the surface at a point where the break showed an angle of 90 degs. with the seam. He wished to ask whether the angle at point *e*, in Fig. 2, Plate I., was a right angle, and whether the lines at the same point in Fig. 5, Plate II., were at right angles? That was, whether the line of fracture was at right angles to the seam of coal when the final subsidence took place?

Mr. WAIN said the question showed that Mr. Henshaw had scarcely followed his remarks at the last meeting. The original paper might lead members to consider that line as being the final line of fracture, and consequently he prepared a new section (Fig. 10)* to illustrate what he proved to be the actual line of fracture eventually. The lines (Figs. 2 and 5) were not intended to show the lines of fracture or subsidence, but the forces actually at work during the opening out of this method of working coal.

Mr. HENSHAW thought he had followed the paper, but he wanted to know whether, in most seams, subsequent lines of fracture were at right angles to the seam? At the Podmore collieries some seams were inclined at an angle of 45 degs. Was it Mr. Wain's opinion, if workings were conducted in such a seam, that the line of fracture or subsidence would correspond to an area over the seam of coal at right angles to the inclination of the seam of coal?

Mr. WAIN considered that was hardly a fair question, because he had already admitted that he had had no experience of seams of high inclination; his paper referred to seams of moderate inclination only.

Mr. W. H. WAIN said in considering this question they must consider the nature of the strata. It appeared that the overlying rock, which was of great thickness, would be suspended; it would be in a state of tension; and, if he might give an opinion, the line of fracture which they might expect to follow would be the line of least resistance, which would be at right angles to the strata. But in softer measures the line of fracture was not at right angles to the dip; it was rather, as Mr. Henshaw indicated, more in the line of repose.

Mr. MITCHESON enquired whether there had been any alteration in the goaf in the two upper seams, and whether if any water had been taken away that made any difference in the position of the break?

Mr. E. B. WAIN replied that there had been no such change. The lines of break in the figures were the actual lines of break in the working-face, and illustrated the forces operating in the coal-getting. Mr. Henshaw spoke of the line of fracture as taking the line of repose and not

* *Trans. Fed. Inst.*, vol. iv., page 516.

the line of least resistance. In soft measures that would happen, but in such measures as had been dealt with in this paper he thought there would be a certain amount of cantilever support, and there would be no breaking-back in such measures as these, and the line of final break would be as nearly as possible at right angles to the dip of the mine.

Mr. STATHAM said there were two cases which had come under his observation, which he should like to mention with regard to the line of breakage. In one case, which had been worked to the rise of the mine up to a down-throw fault (supposed to be 400 yards), the line of break on the surface was 20 yards beyond the point to which the mine had been won. In the other case the line of break on the surface, to the dip of the mine, was about 40 yards beyond the point of a line drawn at right angles to the inclination of the seam. The measures lay at an incline of 1 in 8.

Mr. HAINES said the slip of the fault would produce the extra drawing. If Mr. Henshaw's remarks concerning the angle were correct, he did not know where, in the case of the rearers, the effects would cease. It was an important question, especially where they were working four or five seams, to know where to stay and where to work.

Mr. MITCHESON thought that the nature of the overlying strata had an effect upon the line of fracture. If they had soft measures it was difficult to trace the break, and they were liable to get astray; but he knew a case where a seam was being taken out, the overlying strata being practically all marl: it was rather flat, and there was subsidence a long way beyond a line drawn at right angles to the dip of the seams.

Mr. W. HEATH said he knew a case in which, where there was a dip of 1 in 4, a large building on the surface was fractured, and litigation took place between the surface owners and the colliery proprietors as to the damage. He (Mr. Heath) took the measurements and found that it was exactly at right angles to the working of the mine. There was no rock except the Seven-yards, which was near the surface. The draw might vary under peculiar circumstances; supposing they had a fault that overlay to the dip of the workings, the draw would be farther back. If there was an opposite throw, that might prevent it from travelling back.

Mr. MITCHESON said he did not think they could lay down a hard-and-fast line in these matters. There were cases where the break had not been found at right angles. In South Staffordshire, working under the conglomerate at moderate inclination, they could trace the breaks in advance, when working from dip to rise.

Mr. W. HEATH said that was an exceptional case. Where they had the conglomerate, the draw would move in advance of the face of the

working. Where they had a fault which carried over to the dip, the break would be carried with it. Where they had a weaker stratum, it would be certain to go with it. He supported Mr. Wain in his general view as to the position of the line of fracture, where there was no special circumstance to alter it.

Mr. E. B. WAIN asked Mr. Mitcheson whether the conglomerate deposit was in the same line of dip and conformable with the coal-measures?

Mr. MITCHESON said he could not answer that; in all probability it was not. There was a great thickness, but he could not say whether it was conformable to the coal-measures, as the surface was very hilly.

Mr. HAINES said it would not be a stratified bed.

Mr. R. H. WYNNE said some years ago a case came under his notice in the northern part of the North Staffordshire coal-field, where the line of fracture was as near as possible on the line of the dip. From the dip-line, he found a series of parallel lines of subsidences had taken place in the same direction.

Mr. BLAIKIE asked how deep was the seam?

Mr. WYNNE replied that it was about 150 yards deep.

Mr. W. H. WAIN observed that in Fig. 10, the main break arose from the solid pillar left on the dip side of the main level. Were there any circumstances where they could trace the main break which would arise from the face being stopped on the rise side? because, looking at Fig. 6, Plate I., they would rather expect to trace the line of break from the stoppage of the face: it would be a fall over from gravity.

Mr. E. B. WAIN said in these seams it was difficult to trace that, because there were five or six seams, some of them shallow, and the indications were not reliable. At the same time he should think that in all those cases where subsidence had taken place as the working progressed there was a regular subsidence, and there was not a very great opening or space available for that downward movement that Mr. W. Wain spoke of.

Mr. W. H. WAIN said the method of working would affect the line of break to a great extent. In working, with a thorough longwall system, the goafs well packed as the work advanced, there would be less liability to the phenomena of breaks, and they might depend upon something like regularity in the breaks.

On the motion of Mr. R. H. WYNNE, seconded by Mr. HEATH, the further consideration of the paper was adjourned.

The annual dinner of the members took place at the close of the meeting, and was attended by nearly fifty members.

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE INSTITUTE ROOMS, BARNSLEY, MARCH 18TH, 1893.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members, having been previously nominated:—

MEMBERS—

Mr. JAMES NASMYTH SIDEBOTTOM, Civil and Mining Engineer, Manchester.
Mr. ALEXANDER REID, Colliery Manager, Ffrwd Collieries, Wrexham.

Mr. E. BROWN read the following paper on "Experiments upon two Guibal Fans at St. John's Colliery, Normanton":—

EXPERIMENTS UPON TWO GUIBAL FANS AT ST. JOHN'S COLLIERY, NORMANTON.

By EDWARD BROWN.

Introduction.

At St. John's Colliery, Normanton, the Stanley Main seam at a depth of 110 yards, and the Haigh Moor seam at 282 yards, were worked up to 1886. Each of these seams were separately ventilated, and independently from each other, by two Guibal fans, each 24 feet in diameter and 8 feet wide.

The eastern fan was built in 1871, and is driven by a horizontal engine, with a cylinder 16 inches in diameter and 36 inches stroke, which is fitted with an ordinary D-slide valve; there is no shutter to this fan.

The western fan was built in 1876, and is driven by a horizontal engine, with a cylinder 24 inches in diameter and 24 inches stroke, which is also fitted with an ordinary D-slide valve. This fan is fitted with a Walker anti-vibrating shutter or outlet.

In 1886 it was decided to sink to the Silkstone seam, which lies at a depth of 192 yards below the Haigh Moor and a total depth of 474 yards from the surface. A staple pit was sunk, 14 feet in diameter, from the Haigh Moor to the Silkstone seam. A wooden brattice was put in for ventilation, and the pit was fitted up with wire-rope guides and single-tnb cages, worked by an engine with a pair of 14 inches cylinders driven by compressed air (the engines had been previously used for the sinking). This arrangement provided means for opening out straight-work places, and forming main roads during the sinking and fitting up of the future winding-pit.

It was afterwards decided to sink the Haigh Moor upcast shaft, which was 14 feet in diameter, to the Silkstone seam, and to use it for winding. In order to avoid the serious loss of air inseparable from winding out of an upcast shaft with a closed top, the Stanley Main upcast shaft, which was 14 feet in diameter, was sunk to the Haigh Moor, and the entire ventilation of the three seams was effected by this shaft and the western fan alone. The Haigh Moor upcast shaft was then made a downcast shaft and fitted up for winding, and the staple pit became the upcast shaft for the Silkstone seam. This arrangement placed the eastern fan out of use, but, in order to utilize it as a duplicate fan, a drift was made under the pit-hill, as shown in Figs. 1, 2, 3, and 4, Plate XXII. The drift from

E to F has outward battered side-walls, the bottom inverted to a 7 feet radius, and the top covered by 5 inches by 4½ inches steel girders, of H-section, boarded on the lower flanges and covered with cement concrete (in the proportion of 1 to 6) slightly rounded on the top (Fig. 2, Plate XXII.). The drift from F to G was built to the section shown in Figs. 3 and 4, and covered in the same manner, and was ultimately buried with pit dirt, the whole being quite air-tight. Doors are arranged at each fan, so that either may be run singly, or both fans run together, as desired.

Experiments.

After the connecting-drift was completed, some rough experiments were made which showed that the same volume of air could be exhausted by running both fans together at a much lower speed than was required when running a single fan, and at a much lower expenditure of power.

In order to carry out these experiments systematically, and to obviate as far as possible any liability to error, forms were ruled and fixed on boards whereon the various observations were recorded.

The experiments were made during half an hour, with half an hour interval between each, so as to allow of the conditions becoming steady after the change in the speed of the fan. Three diagrams were taken from both ends of each engine, for each speed of each fan.

Two readings were taken of the anemometer (each of eight minutes' duration) for each fan at each speed. The anemometer was held for half a minute in each of the sixteen divisions into which the eastern drift (Fig. 3), and western drift (Fig. 5, Plate XXII.) were divided. The average speed of the air per minute is the quotient of this reading divided by 8, plus the constant 30 (the result of tests at Kew of both of the anemometers used in the experiments).

Tabular forms were used to record the results of the experiments, including the readings of the water-gauge, barometer, thermometer, anemometer, etc., and were placed for that purpose in each engine-house and in each fan-drift.

Before any experiments were made it was agreed to take trial readings with the water-gauge in each of the sixteen divisions into which the drift was divided at the western fan (Fig. 5, Plate XXII.) to see whether it would be necessary to take water-gauge readings in each of these divisions when measuring the air. A small funnel was fixed to the end of an india-rubber tube connected to a water-gauge, and three readings were taken in each division:—(*a*) with the funnel at right-angles to the current of air, (*b*) with the funnel in the direction of the current, and (*c*) with the funnel facing the current. Similar observations were made in each of

the sixteen divisions of the drift to the eastern fan, and are recorded in Tables I. and II. The results, with the funnels held in the positions *a* and *b* are practically the same, and it was arranged that the water-gauge reading should be made before and after each air-measurement, with the tube at right angles to the air and close to the divisions, in each of which the air was measured. The funnel was not used, but the pipe-end was covered with two thicknesses of flannel cloth.

It will be noticed that the reading with the funnel against the current at the eastern fan is nearly the same as the other two readings, the difference being only 0·026 inch; while there is a difference of 0·086 inch at the western fan. This difference is no doubt due to the dissimilar areas of the two airways, the eastern airway being much larger in area than the western one, and consequently there was a much lower velocity of the air to the eastern fan.

It will be observed from Fig. 1, Plate XXII., that the entrance-doors to the fan-drifts are between the position where the air was measured and the fans, so that the scale through these doors was not measured and the water-gauge between that position and the fans was not credited to the fans.

In calculating the indicated horse-power, the three diagrams taken from each end of each cylinder were measured, and the average pressure taken for each particular speed of each engine. A Hopkinson indicator was used for the eastern engine, with a spring of 20 lbs. per inch for Nos. 3 and 4 experiments, and a 30 lbs. spring for the others. A Richards indicator was used for the western engine with a spring of 24 lbs. per inch during all the experiments.

After the results were tabulated it was found that the useful effect, as calculated from the water-gauges observed in the drifts where the air was measured, were very low. It was decided to run the fans at as nearly as possible the same speeds as when the experiments were made, and to take readings with the tube of the water-gauges placed close to the inlet of the fans. The useful effects calculated from these water-gauge readings are shown in column 20 of Table III. The readings were taken at seven different points (Fig. 6, Plate XXII.), and the results are recorded in Table IV.; the efficiencies (column 20, Table III.) were calculated from the average readings of the water-gauge in the several positions. It would have been unfair to take either the highest or the lowest readings, seeing that they varied as much as 13·63 per cent. above and 9·01 per cent. below the mean, or a total variation of 22·64 per cent.

The author wishes particularly to point out how easy it would be to make results vary enormously, depending chiefly upon the point and position in which the air may be measured and the water-gauge readings taken.

Great care was exercised in making these experiments so as to arrive at as a correct result as possible, as it would serve no good purpose to favour either the fan singly or the two when running together. The fans were not coupled by the drift with a view to economy, but as a means of utilizing the eastern fan as an auxiliary in case of accident, or in case of repairs being required by the western fan. It was found by the experiments that considerable economy was obtained by running both fans together, as compared with the use of a single fan at a higher speed.

Table V. containing the results of further water-gauge experiments shows very clearly the variations in the water-gauge in each of the seven positions; Nos. 1 and 6 positions giving the highest readings in nearly every case, while Nos. 3 and 4 give the lowest. Two readings were made: one with the barometer at 29·10 inches, and the other with the barometer at 30·22 inches. The water-gauge was also taken in each engine-house and the theoretical water-gauge is obtained by calculation.

Conclusions.

On referring to Table III., it seems that experiments Nos. 1, 2, and 3 were made with both fans running together; no higher speed could be tried of both fans together; as the eastern fan had the throttle-valve fully open in order to drive its fan at 74·33 revolutions per minute (the boiler pressure being 50 lbs. per square inch). Nos. 4*a* and 5*a* experiments were made on the eastern fan alone at 64·66 and 69 revolutions per minute respectively, the throttle-valve being fully open at the higher speed. Nos. 4*b*, 5*b*, 6, 7, 8, and 9 experiments were made upon the western fan alone. Column 14 shows the number of cubic feet of air produced per horse-power. At the first glance the results may appear to be in favour of running one fan alone, seeing that the eastern fan running alone at 64·66 revolutions per minute produced 1,837 cubic feet per horse-power, and the western fan alone at 65·2 revolutions per minute yielded 2,057 cubic feet of air per horse-power; while both fans running together only exhausted 1,668 cubic feet per horse-power. It will be noticed, however, that the two fans running together discharged 131,985 cubic feet of air per minute, while each fan running singly at approximately the same speed is only discharging 106,564 and 110,896 cubic feet of air per minute respectively.

Probably the fairest mode of comparison will be to take the horse-power required to produce the same volume of air, and Table III. contains three cases where approximately the same quantity was obtained. In experiment No. 1, both fans running at about 65 revolutions per minute

produced 131,985 cubic feet of air per minute with 79·10 horse-power, or 1,668 cubic feet of air per horse-power. In experiment No. 7, the western fan alone at 79·60 revolutions per minute produced 131,067 cubic feet of air with 91·35 horse-power, or 1,435 cubic feet of air per horse-power against 1,668 cubic feet, that is, 14 per cent. less than when running both fans together.

In No. 2 experiment, both fans running together at about 70 revolutions per minute produced 139,147 cubic feet of air with 93·83 horse-power, or 1,483 cubic feet per horse-power. In No. 8 experiment, the western fan alone at 83·70 revolutions per minute produced 139,289 cubic feet of air with 105·90 horse-power, or 1,315 cubic feet per horse-power against 1,483 cubic feet, being about 11·5 per cent. in favour of running both fans together.

In No. 3 experiment, both fans running at about 75 revolutions per minute produced 148,763 cubic feet of air with 113·09 horse-power, or 1,315 cubic feet of air per horse-power. In No. 9 experiment, the western fan alone at 91·15 revolutions per minute produced 147,367 cubic feet of air with 133·80 horse-power, or 1,101 cubic feet per horse-power against 1,315 cubic feet, being 17 per cent. in favour of running both fans together.

Briefly, the two fans running at about 75 revolutions per minute produced the same volume of air as the single fan did at 91 revolutions per minute with a lessened expenditure of 20·71 horse-power.

It would be very interesting to know what would be the result if a third fan, of the same construction as the two now in use, was put down and exhausted from the same upcast shaft.

With the two fans running together the manometric efficiency (Table III., column 17), *i.e.*, the water-gauge reading in the drift divided by the calculated water-gauge due to the periphery speed of the fan, averages ·56 for Nos. 1, 2, and 3 experiments, and the mechanical efficiency (column 19), *i.e.*, the horse-power in the air (calculated from the water-gauge observed in the engine-house) ÷ by the horse-power of the engine is ·53; the mechanical efficiency (column 18), *i.e.*, the horse-power in the air (calculated from the drift water-gauge) ÷ by the horse-power of the engine, only equals ·46. This result is lower by 10 and 7 per cent. respectively than that of the western fan running alone. The results contained in columns 17 and 18 approximate very closely, but the results are low; while column 19 keeps fairly constant and gives an average for the six experiments, Nos. 4*a*, 5*a*, 6, 7, 8, and 9, of ·59, which may be considered a fairly satisfactory result.

APPENDICES.

TABLE I.—EXPERIMENTS WITH THE WATER-GAUGE ON THE WESTERN FAN.

Position of Water-gauge.	With the Tube and Funnel		
Number of Divisions.	At Right-angles to the Current. (a)	In the Direction of the Current. (b)	Facing the Current. (c)
1	1·700	1·700	1·680
2	1·650	1·650	1·625
3	1·625	1·650	1·600
4	1·650	1·675	1·600
5	1·700	1·675	1·600
6	1·600	1·650	1·550
7	1·625	1·650	1·550
8	1·600	1·625	1·500
9	1·600	1·625	1·500
10	1·650	1·650	1·500
11	1·650	1·650	1·550
12	1·625	1·625	1·500
13	1·600	1·625	1·550
14	1·600	1·625	1·550
15	1·625	1·625	1·525
16	1·650	1·650	1·600
Averages ...	1·634	1·647	1·561

TABLE II.—EXPERIMENTS WITH THE WATER-GAUGE ON THE EASTERN FAN.

Position of Water-gauge.	With the Tube and Funnel		
Number of Divisions.	At Right-angles to the Current. (a)	In the Direction of the Current. (b)	Facing the Current. (c)
1	1·50	1·55	1·55
2	1·55	1·55	1·55
3	1·55	1·55	1·50
4	1·55	1·55	1·55
5	1·60	1·55	1·55
6	1·60	1·60	1·55
7	1·55	1·55	1·55
8	1·55	1·55	1·50
9	1·55	1·55	1·50
10	1·55	1·55	1·50
11	1·55	1·60	1·55
12	1·60	1·55	1·55
13	1·55	1·60	1·55
14	1·60	1·60	1·55
15	1·60	1·60	1·60
16	1·60	1·60	1·60
Averages ...	1·565	1·569	1·543

TABLE III.—RESULTS OF THE EXPERIMENTS.

No. of Experiment.	Conditions of Experiment.	Revolutions of Fans per Minute.	Volume of Air.		Water-gauges.				Indicated Horse-power of Engines.	Total.	Horse-power in Air.			Volumes of Air per Horse-power.			Manometric Efficiency	Mechanical Efficiencies.		
			Cubic Feet per Min.	Cubic Feet per Min.	In Fan Drift.	In Eastern Engine-house.	In Western Engine-house.	Theoretical.			Calculated from Drift W.-gauge.	Calculated from Engine-house Water-gauge.		Col. 4. / Col. 10.	Col. 4. / Col. 11.	Col. 4. / Col. 13.	Col. 8. / Col. 5.	Col. 10. / Col. 11.	Col. 13. / Col. 10.	Calculated from Inlet W.-gauge.
					Ins.	Ins.	Ins.	Ins.						C. Ft.	C. Ft.	C. Ft.				
1	Both fans running together	E 65·33 W65·00	E 68,746 W63,230	131,985	1·70	2·05	1·95	3·084	E 44·38 W34·72	79·10	35·35	E 22·12 W19·43	41·55	1,668	3,733	3,176	·5512	·4469	·5252	·4719
2	Do.	E 70·00 W70·23	E 63,719 W75,428	139,147	2·00	2·26	2·30	3·565	E 46·96 W46·87	93·83	43·85	E 22·69 W27·33	50·09	1,483	3,173	2,783	·5610	·4673	·5330	·5023
3	Do.	E 74·33 W75·93	E 69,750 W79,013	148,763	2·30	2·60	2·72	4·050	E 56·85 W56·24	113·09	53·91	E 26·86 W33·86	60·72	1,315	2,759	2,450	·5679	·4767	·5371	·5057
4*a*	Eastern fan alone ...	64·66	—	106,564	1·40	1·90	—	3·033	—	58·00	23·50	—	31·90	1,837	4,534	3,340	·4615	·4051	·5500	·5208
4*b*	Western fan alone ...	65·20	—	110,896	1·15	—	1·90	3·084	—	53·90	20·09	—	33·20	2,057	5,520	3,347	·3728	·3708	·6128	·4836
5*a*	Eastern fan alone ...	69·00	—	112,528	1·60	2·20	—	3·454	—	69·95	28·37	—	39·00	1,608	3,966	2,885	·4632	·4055	·5575	·4992
5*b*	Western fan alone ...	69·55	—	114,207	1·25	—	2·05	3·510	—	62·46	22·49	—	36·90	1,828	5,078	3,095	·3561	·3600	·5907	·4779
6	Do.	75·85	—	122,750	1·40	—	2·26	4·174	—	77·40	27·08	—	43·71	1,586	4,532	2,808	·3354	·3498	·5647	·4579
7	Do.	79·60	—	131,067	1·60	—	2·65	4·597	—	91·35	33·34	—	54·73	1,435	3,931	2,394	·3698	·3649	·5991	·4720
8	Do.	83·70	—	139,289	1·75	—	3·00	5·079	—	105·90	38·41	—	65·84	1,315	3,626	2,115	·3445	·3627	·6217	·5139
9	Do.	91·15	—	147,367	1·95	—	3·40	6·022	—	133·80	45·28	—	78·95	1,101	3,254	1,866	·3238	·3384	·5900	·4564
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

TABLE IV.—EXPERIMENTS WITH THE WATER-GAUGE.

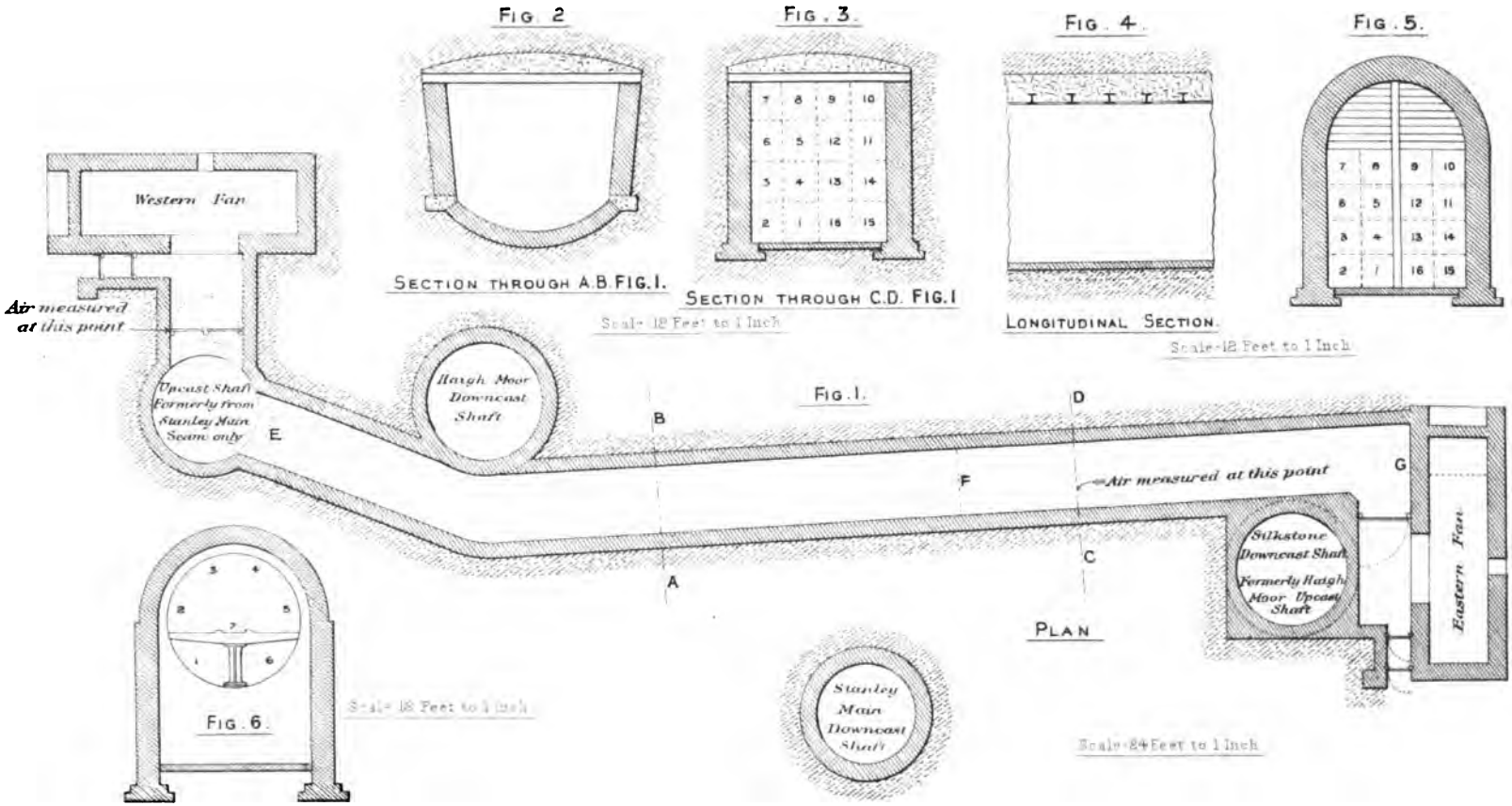
No. of Experiment.	Conditions of Experiment.	Name of Fan.	Revolutions of Fan.	Position of Water-gauge at Inlet.							
				1.	2.	3.	4.	5.	6.	7.	Means.
				Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	Western fan alone	Western	65	1·70	1·50	1·40	1·40	1·55	1·60	1·40	1·50
2	Do.	Do.	70	1·90	1·70	1·60	1·50	1·65	1·70	1·60	1·66
3	Do.	Do.	75	2·00	1·90	1·75	1·70	1·85	1·90	1·80	1·84
4	Do.	Do.	80	2·35	2·10	2·00	1·85	2·10	2·15	1·95	2·07
5	Do.	Do.	85	2·60	2·55	2·45	2·35	2·50	2·60	2·35	2·48
6	Do.	Do.	90	2·90	2·70	2·60	2·35	2·60	2·75	2·50	2·63
7	Both fans running together	Eastern	65	1·95	1·90	1·90	1·80	1·75	1·80	1·85	1·85
		Western	65	1·80	1·80	1·70	1·70	1·75	1·75	1·75	1·75
8	Do. do.	Eastern	70	2·30	2·30	2·25	2·10	2·10	2·15	2·15	2·19
		Western	70	2·10	2·10	2·10	2·00	2·05	2·05	2·05	2·06
9	Do. do.	Eastern	75	2·50	2·50	2·50	2·40	2·35	2·40	2·50	2·45
		Western	75	2·50	2·45	2·40	2·40	2·45	2·45	2·40	2·43

TABLE V.—EXPERIMENTS WITH THE WATER-GAUGE.

No. of Experiment.	Conditions of Experiment.	Name of Fan.	Barometer.	Revolutions of Fan.	Water-gauge.									
					Engine-house.	Position at Inlet.								Theoretical.
						1.	2.	3.	4.	5.	6.	7.	Means.	
			Inches.		Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	Western fan alone	Western	29·10	65	1·65	1·25	1·10	1·05	1·00	1·15	1·15	1·05	1·10	3·04
			30·22	65	1·75	1·40	1·35	1·20	1·20	1·25	1·40	1·25	1·29	3·04
2	Do.	Do.	29·10	70	1·85	1·50	1·35	1·15	1·20	1·30	1·30	1·30	1·30	3·52
			30·22	70	1·90	1·60	1·50	1·40	1·40	1·50	1·60	1·40	1·48	3·52
3	Do.	Do.	29·10	75	2·10	1·60	1·40	1·40	1·35	1·45	1·50	1·40	1·44	4·05
			30·22	75	2·10	1·70	1·60	1·50	1·55	1·60	1·70	1·50	1·59	4·05
4	Do.	Do.	29·10	80	2·40	1·85	1·70	1·55	1·60	1·80	1·80	1·60	1·70	4·60
			30·22	80	2·35	1·95	1·90	1·70	1·70	1·90	1·95	1·75	1·83	4·60
5	Do.	Do.	29·10	85	2·70	2·10	1·95	1·85	1·80	1·90	2·00	1·80	1·91	5·20
			30·22	85	2·55	2·25	2·00	1·85	2·00	2·20	2·20	1·90	2·05	5·20
6	Do.	Do.	29·10	90	3·00	2·50	2·25	2·10	2·10	2·20	2·25	2·00	2·20	5·83
			30·22	90	3·15	2·55	2·40	2·20	2·20	2·40	2·50	2·20	2·35	5·83
7	Both fans running together	Western	29·10	65	1·90	1·60	1·60	1·55	1·50	1·60	1·55	1·55	1·56	3·04
		Eastern	29·10	65	1·90	1·85	1·95	1·90	1·80	1·80	1·80	1·75	1·83	3·04
		Western	30·22	65	2·00	1·70	1·70	1·65	1·70	1·70	1·70	1·70	1·69	3·04
		Eastern	30·22	65	2·00	2·00	2·00	2·00	1·85	1·85	1·85	1·75	1·90	3·04
8	Do. do.	Western	29·10	70	2·25	2·00	1·90	1·90	1·90	1·90	1·95	1·92	1·92	3·52
		Eastern	29·10	70	2·25	2·15	2·20	2·20	2·15	2·10	2·10	2·10	2·14	3·52
		Western	30·22	70	2·30	2·05	2·00	1·95	2·00	1·95	2·00	1·95	1·98	3·52
		Eastern	30·22	70	2·30	2·27	2·25	2·27	2·20	2·20	2·20	2·25	2·23	3·52
9	Do. do.	Western	29·10	75	2·55	2·25	2·20	2·05	2·05	2·10	2·10	2·10	2·12	4·05
		Eastern	29·10	75	2·50	2·40	2·55	2·45	2·40	2·35	2·40	2·35	2·41	4·05
		Western	30·22	75	2·60	2·25	2·20	2·20	2·20	2·20	2·25	2·20	2·21	4·05
		Eastern	30·22	75	2·60	2·50	2·60	2·55	2·45	2·45	2·45	2·35	2·48	4·05

Federated Institution of Mining Engineers
Transactions 1892 93

To illustrate Mr. E. Brown's "Experiments upon Two Guibal Fans at St. John's Colliery, Normanton".



Midland Institute of Mining, Civil & Mechanical Engineers.
Transactions Vol. 2 3

And. Reid Sons & Co. Lithos Newcastle

The PRESIDENT said that before discussing the paper it would be their pleasure to pass a vote of thanks to Mr. Brown for the great trouble he had taken in preparing the paper, and the interesting matter embraced in it. The paper came at an opportune time, as the Institute had appointed a committee to make investigations respecting fans, and the information given by Mr. Brown would form a valuable addition to that obtained from other sources. He had great pleasure in proposing a vote of thanks to Mr. Brown for his valuable and interesting paper.

Mr. J. NEVIN said, in seconding the motion, that it was not often they had the opportunity of comparing two fans in a situation where one or both could be used on the same shaft.

The motion was carried unanimously.

The PRESIDENT said the experiments proved that the best results were obtained from both fans working together, and asked Mr. Brown if he had taken into account the natural ventilation due to the temperature of the shafts?

Mr. BROWN replied that no corrections had been made.

The PRESIDENT asked if there were any steam-pipes in the shafts?

Mr. BROWN replied that there was one steam-pipe in the downcast shaft.

The PRESIDENT said that the fans would give better results if the steam-pipe had been in the upcast instead of in the downcast shaft.

Mr. BROWN agreed with the President's remark.

The PRESIDENT said the fan appeared to give a better result when running at a low speed, indicating 79 horse-power, than when indicating 106 horse-power.

Mr. BROWN replied that the quantity of air did not increase with the number of revolutions of the fans.

Mr. A. B. SOUTHALL said the resistances to the ventilation would be the same whether one or two fans were working, so that Mr. Brown's paper showed the advantage of using two fans, and not the difficulties to be overcome in circulating that quantity of air.

Mr. J. LONGBOTHAM said that the Framwellgate colliery, in the county of Durham, was ventilated, at one time, by means of a furnace. A Guibal fan 30 feet in diameter was subsequently erected in place of the furnace. When the workings were getting a long distance in-bye, it was suggested that it might be desirable to use the furnace to assist the fan. The furnace was lighted, with the result that the volume of air going into the workings diminished, although the quantity of air going through the fan was increased.

The PRESIDENT said that effect was perhaps owing to rarefaction, and the fan could not pass the same quantity.

Mr. SOUTHALL asked if the fans exhausted air from the same upcast shaft?

Mr. BROWN—Yes.

Mr. SOUTHALL enquired whether, in the experiments with the single fans, both fans exhausted from the same shaft?

Mr. BROWN answered, Yes, but the other fan was standing; when trying one fan they shut the door and stopped the other fan. The anemometer was held for 30 seconds in each division of the airway at the place of measurement. Sometimes the air seemed to have a preference for one fan rather than the other, and there was from 7,000 to 10,000 cubic feet per minute difference in the results of some of the experiments with each fan approximately at the same speed.

The PRESIDENT said they got a general idea by a discussion like this which helped them in reading the paper at home. They could not now discuss the paper with justice to Mr. Brown and the trouble he had had in preparing statistics, but this difference of 22 per cent. in the water-gauge, taken in one position and another, was surprising to him.

Mr. T. W. H. MITCHELL said he was lucky enough to be appointed engineer to the committee to make experiments for the Institute. The instructions they had were to turn the tube towards the fan, and to put a flannel over it, but not at right angles as he understood Mr. Brown had done.

Mr. BROWN said the result would depend on the speed of the air in the drift. With the western fan there was a difference of 0·08 inch in the water-gauge readings, and in the eastern fan it was practically the same, because the airway was so much larger. The tube was placed across the drift because one airway was smaller than the other.

The PRESIDENT said it was a fact that a small fan at a high periphery speed gave a greater water-gauge than a large fan at the same speed. In years to come it would not be a question merely of having the power necessary to drive the fans, but also of dealing with the temperature. They would have to pass a larger volume of air. For instance, at Ashton Moss they were dealing with a temperature of 84 to 87 degs. Fahr.

Mr. LONGBOTHAM moved that the discussion be adjourned.

Mr. THIRKELL seconded the motion, which was agreed to.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, APRIL 8TH, 1893.

Sir LOWTHIAN BELL, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings of March 25th, and of that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. M. W. BARKER, Engineer, P.O. Box 1,463, Johannesburg, Transvaal

Mr. HENRY B. BUNKELL, Engineer, P.O. Box 962, Johannesburg, Transvaal.

Mr. WILLIAM YOUNG CAMPBELL, Mining Engineer, etc., P.O. Box 357, Johannesburg, Transvaal.

Mr. WILLIAM CHARLTON, Mining Engineer, Linares, Provincia de Jaen, Spain.

Mr. SHERARD OSBORN COWPER-COLES, Manager, London Metallurgical Company, Limited, 80, Turnmill Street, London, E.C.

Mr. JAMES HUBERT DANGAR, Mining Agent, Camborne, Cornwall.

Mr. J. HUBERT DAVIES, Electrical Engineer, P.O. Box 455, Johannesburg, Transvaal.

Mr. ALFRED DUMAT, Mechanical and Railway Engineer, 1, Loop Street, Pietermaritzburg, Natal.

Mr. E. W. EVANS, Mining Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. LOUIS FARAGHER, Mine Agent, Cape Copper Co., Ld., Ookiep, Namaqualand, South Africa.

Mr. ALBERT H. HALDER, Consulting Engineer, Pietersburg, Transvaal.

Mr. J. KERR HOULGATE, Mining Engineer, 69, Lowther Street, Whitehaven.

Mr. JOHN ARTHUR JONES, Mining Engineer and Analytical Chemist, Gijon, Asturias, Spain.

Mr. JOHN O'GORMAN LALOR, Mining Engineer and Metallurgist, P.O. Box 357, Johannesburg, Transvaal.

Mr. HENRY LAKIN LAWRENCE, Mining Engineer, Mines de Pierrefitte, Pierrefitte-Nestalas, Hautes Pyrénées, France.

Mr. RICHARD A. D. LIEBERT, Mechanical Engineer, P.O. Box 357, Johannesburg, Transvaal.

Mr. ROBERT H. LONGBOTHAM, Mining Engineer, Westgate, Wakefield.

Mr. DAVID ALEXANDER LOUIS, Metallurgical and Mining Engineer, 77, Shirland Gardens, London, W.

Mr. JOHN S. MACARTHUR, Metallurgist, 12, Knowe Terrace, Pollokshields, Glasgow.

Mr. JOHN HODGSON NICHOLSON, Mining Engineer, Seaton Delaval Colliery, Northumberland.

Mr. FRANCIS DANIEL PETER, Mining Engineer, Greymouth, New Zealand.

Mr. JOHN GUNSEN SELKIRK, Mining Engineer, Dalton-in-Furness.

Mr. A. HUMBOLDT SEXTON, Professor of Metallurgy, Metallurgical Department, Andersonian Buildings, 204, George Street, Glasgow.

Mr. CHARLES LIDDELL SIMPSON, Mechanical Engineer, Engine Works, Grosvenor Road, Pimlico, London.

Mr. ARTHUR JAMES STEVENS, Mechanical Engineer, Uskside Ironworks, Newport, Monmouthshire.

Mr. W. HENWOOD TRELEASE, Chief Agent of the Pestarena United G. M. Co., Ld., Pestarena, Vall'Anzasca, Novara, Italy.

ASSOCIATE—

Mr. JOSEPH THOMPSON, Overman, 38, Church Street, Murton Colliery.

The following gentlemen were nominated for election :—

MEMBERS—

Mr. H. M. BECHER, Mining Engineer, 9, D'Almeida Street, Singapore.

Mr. J. C. S. BEYNON, Civil and Mining Engineer, P.O. Box 1,364, Johannesburg, Transvaal.

Mr. GEORGE DAVEY, Mining Engineer and Metallurgist, Ferro-carril Michoacan y Pacifico, Maravatio, Mexico.

Mr. STANLEY H. FORD, Mine Agent, Stolzenfels, Great Namaqualand, South Africa.

Mr. THOMAS GILCHRIST, Mining Engineer, Manor House, Penshaw.

Mr. GEORGE LINDAY, Colliery Manager, Blackett Colliery, Haltwhistle, Northumberland.

Mr. WILLIAM ERNEST LISHMAN, M.A., Viewer, Bunker Hill, Fence Houses.

Mr. J. S. QUIRK, Metallurgist, St. Helens Lead-Smelting Works, St. Helens, Lancashire.

Mr. F. G. SHAW, Mining Engineer, London.

Mr. EDMUND SPARGO, Mining Engineer, 3, Cable Street, Liverpool.

Mr. CHARLES ROBERT WESTERN, Engineer, Broadway Chambers, Westminster, London, S.W.

Mr. JOSEPH HENRY WOOLCOCK, Civil and Mining Engineer, 49, Lowther Street, Whitehaven.

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Mr. ALEXANDER A. JAMES, Under Manager, Croxdale, near Durham.

Mr. JOHN W. THOMPSON, Colliery Surveyor, Backworth Colliery, Newcastle-upon-Tyne.

AWARDS FOR PAPERS.

The SECRETARY read the following lists of papers for which prizes had been awarded to the authors:—

YEAR 1890-91 (Conclusion).*	
NAME.	TITLE OF PAPER.
M. Walton Brown ...	Experiments with Explosives used in Mines.
M. Walton Brown ...	The Waddle Patent (1890) Fan.
W. Cochrane	On a Duplex Arrangement of Centrifugal Ventilating Machines.
J. Kenneth Guthrie ...	Pumping Appliances at Eltringham Colliery.
A. L. Steavenson	Notes on the Present Position of the Question of Transmission of Power.
YEAR 1891-92.	
P. Phillips Bedson and W. McConnell	Notes on the Gases enclosed in Coal and Coal-dust.
D. Selby Bigge	The Practical Transmission of Power by Means of Electricity and its Application to Mining Operations.
M. Walton Brown ...	The Rateau Ventilator.
L. W. Chicken	Experiments with Explosives.
W. Garnett	The Electric Transmission of Power and its Analogies in Hydraulics.
E. Halse	Notes on the Occurrence of Manganese Ore near Mulegé, Baja California, Mexico.
E. Halse	Notes on the Occurrence of Manganese Ore near the Arenigs, Merionethshire.
H. D. Hoskold	Notes upon the Mines in the Argentine Republic, South America.
J. D. Kendall	The Iron Ores of Spain.
J. M. Liddell	The Witwatersrandt Gold-field.
W. J. Orsman	Notes on the Products and Temperature of Detonation of some High Explosives.
W. J. Orsman	The Detonation of High Explosives by Percussion.
H. Palmer	Notes on an Electric Transmission Plant at East Howle Colliery.
J. L. Shaw...	The Hæmatite Ores of Cumberland.
T. H. M. Stratton... ...	An Enquiry into the Cause of the two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884.
R. T. Swallow	Description of a Method of Removing Deposits from the inside of Rising Main Pipes in Shafts.

* See also *Trans. Fed. Inst.*, vol. ii., page 472.

DISCUSSION UPON MR. JAMES LESLIE SHAW'S PAPER ON "THE HÆMATITE ORES OF CUMBERLAND."*

Mr. J. D. KENDALL wrote that as Mr. Shaw had tacitly refused to abide by the decision of a third party in the matters of fact in difference between himself and the writer, there was, of course, an end to argument based on premises involving these disputed facts. There was still something to be noticed in Mr. Shaw's latest reply.† It was most difficult to make out with anything like certainty what Mr. Shaw wished members to understand from this contribution to the discussion. One thing, however, seemed fairly clear, *i.e.*, that he had completely abandoned the cavern explanation with which he set out. When endeavouring to account for the shale partings in the ore, he said‡ "the wearing action on the limestone, and the deposition of iron may have gone on simultaneously . . . . so that while the limestone was being softened and worn by acidulated water . . . . at the same time and from the same water iron was being deposited." Again, he said,§ "the two processes of wasting and deposition may have gone on simultaneously in all cases." Unless we are prepared to give up the accepted meaning of the word "cavern," it surely never can be said that this is a description of a cavernous deposition. It, to all intents and purposes, describes a replacement, but whether chemical or physical, it was impossible to make out, as Mr. Shaw had not yet thought it worth while to enlighten us as to the particular mode in which he conceived the ore to have been deposited, notwithstanding the writer's repeated requests that he would do so. Once again, will Mr. Shaw tell us in what chemical or physical form the iron was, that he supposed to have been deposited from the acidulated water, and how it was, in the first instance, separated from the enormous amount of siliceous and argillaceous matter with which he assumed it to have once been associated? As an excuse for not referring in his original paper to interbedded shales, Mr. Shaw said ‖ that he "had never seen the necessity of bringing in shale-beds to support his opinion on the formation of hæmatite, and he did not therefore think it necessary to ask Mr. Kendall where the shale-beds . . . . were to be seen." Surely this statement, if meant, showed that Mr. Shaw lacked true scientific method. Writers in search of truth—and not merely anxious to bolster up a preconceived opinion—put forward all the facts, and not simply those that accord with their hypotheses. If Mr. Shaw knew anything of the

* *Trans. Fed. Inst.*, vol. iii., page 580. † *Ibid.*, vol. iv., page 147.
‡ *Ibid.*, page 147. § *Ibid.*, page 149. ‖ *Ibid.*, page 148.

literature of hæmatite he must have known that shale-beds were looked upon (by some writers at any rate) as an unanswerable argument against the cavernous explanation of hæmatite deposition, and, seeing that he adopted the cavernous explanation in his paper, he was morally and scientifically bound to notice the shale-beds and reconcile their existence with his theories. Why Mr. Shaw should refer to the Mammoth Cave of Kentucky was inconceivable, seeing that in his latest reply he avoided the necessity for caverns; but it might increase his confidence in his new position to be told that the span of the largest chamber in the Kentucky cave was not one-third of that of the Gillfoot Park deposit adjoining the cemetery. Notwithstanding that fact, its floor was covered with enormous blocks, which had fallen from the roof; whereas, there was not a particle of evidence that any stone had fallen from the roof of the Gillfoot Park deposit. Mr. Shaw, it appears, now* assumed that the writer had no previous acquaintance with the Gillfoot Park deposit, because the section accompanying his (the writer's) first remarks upon Mr. Shaw's paper was not drawn to scale. If Mr. Shaw's other conclusions were based on premises so slender, it was not surprising that they were lacking in accuracy. When the writer sketched the section referred to, it would have been quite possible for him to have drawn that section to scale. It was, however, unnecessary, as the section was simply intended to illustrate the parallelism of the bedding-planes in the limestone and shale to the ore-bed. The expression "growing together" was still objected to by Mr. Shaw, but he did not suggest a better one, nor show how its employment might lead to misconceptions. It was an expression in common use among miners, and, in the writer's opinion, one that expressed the fact tersely. Mr. Shaw's reference to the formation of flints in explanation of his phrase "affinity of particles" reminded one of attempts that were sometimes made, in another region of thought, to explain phenomena by assumptions—the assumption being as difficult to understand as the phenomena themselves. If "affinity of particles" meant the same as the "mechanical attraction of particles," what did the latter mean, and how did it operate in the formation of iron ore?

The CHAIRMAN then declared the discussion closed.

Mr. A. L. STEAVENSON read the following paper by Mr. Edward S. Wight, on "Queensland Coal-mining; and the Method Adopted to Overcome an Underground Fire":—

* *Trans. Fed. Inst.*, vol. iv., page 148.

QUEENSLAND COAL-MINING; AND THE METHOD ADOPTED TO OVERCOME AN UNDERGROUND FIRE.

By EDWARD S. WIGHT.

This paper is written with the object of giving some little idea of coal-mining in Queensland, and the trouble experienced from underground fires. The writer trusts it may prove instructive to some of the members, and that a more graphic account may be presented at some future time.

The coal-seams lie in the Permo-Carboniferous formation, and are both numerous and thick, covering a large area around Bundamba and Ipswich. Coal has also been found in various other parts of the colony, including Jimbour, Townsville, Cooktown, and Nosa, but this paper will be confined to the Ipswich coal-field, as the writer has not visited any of the others; it excludes also the Burrum coal-field, near Maryborough, where a large quantity of coal is raised, and where the systems of working are much the same.

The most successful mines are owned by private individuals, who either own the land or have leased the coal at a royalty of about 6d. per ton. The owners or lessees manage their own mines and perform part of the manual labour besides, as the price obtained for the coal will not pay the high salaries for manager, secretary, shipping agent, office rents, and directors' fees necessitated by properly formed companies; to make a profit, all must be workers.

The principal collieries on the south side of the Bremer river, which divides Ipswich, are the New Chum, Lewis Thomas, Stafford Bros., and West Moreton. The shaft at West Moreton colliery, the deepest in the colony, is 640 feet deep: it is of oblong shape, 15 feet by 6½ feet, divided by a wooden brattice, 8 feet being used as a winding and a downcast shaft, the remainder being used as an upcast shaft. The winding engine has two direct-acting cylinders 22 inches in diameter, with two drums 11 feet in diameter, one of which is fitted with clutch gear. The pulleys, 11 feet in diameter, are set on a substantial and well-designed hardwood framing. The cages are two-decked, and carry two 7 cwt. tubs on each deck. This is the best winding-plant in the colony. The seam worked is 19 feet in thickness, dipping westward at the rate of 1 in 3; only 7 feet of this seam

is at present worked, containing one stone band 8 inches thick; 5 feet, however, above this is workable coal if only proper means of cleaning it were erected, such as the belt screens lately described in the Transactions of this Institute. The coal contains about 7 per cent. of ash, and burns freely and well for both steam and household purposes. The coal is seldom screened, the system adopted being that of riddling underground, and leaving the slack in the mine, as there is no market for the whole of it. The price paid to the miner is 3s. 4d. per ton, which prevails all over the district; for this wage the miner gets and riddles the coal, sets his own timber, lays the road and wheels the coals, sometimes a distance of 300 yards. The miners thereby earn 9s. to 11s. per day of 9 hours, while the rate paid for taking a miner off the coal to datal work is 8s. per day; other wages are about 7s. per day; mechanics, 8s. to 9s. per day; and boys, 3s. to 6s., according to size.

The prevailing method of working is bord-and-pillar, leaving small pillars to crush, with no intention of taking them out. But some of the mines, with the seam at a less inclination, leave larger pillars which may be worked when coming back. In place of brattice, the miners form an intake and return airway by gob, composed of the slack left in the mine and kept up at the roadside by slabbing and props.

The slack is liable to spontaneous combustion, and the gobs should either be levelled over after the bords are done, or each district securely sealed up; the latter plan is probably the better, as it enables air-currents to be shortened.

An attempt was made by Mr. Lewis Thomas to utilize the slack in the manufacture of fuel briquettes; he erected a plant and made a few hundred tons of fuel, but owing to the high cost of pitch the system was abandoned.

No attempt has been made to produce different sizes of coal; the two varieties being simply riddled coal (a $\frac{3}{8}$ inch riddle being generally used) and slack.

The largest output from any one mine is 500 tons per day, but this has not been obtained from one shaft. There are numerous small mines opened by working men, who are afforded a splendid opportunity of commencing for themselves in this way by the Government providing all rolling stock; and in fact nearly all the mines have been thus opened out by working men.

The working of the mines is controlled by an Act of the Queensland Parliament, which came into force at the beginning of 1890, the principal clauses being:—Formation of two means of outlet; the use of

detaching hooks; the formation of special rules; moreover, enginemen must now be certificated, and are not allowed to work more than eight hours (in this respect it is a step in advance of the English Mines Act, and a step too far when there is no compulsion with respect to the management).

The coal on the south side of the Bremer river is non-coking, but on the north side another series of seams occur from which a very good coke is made and finds a ready market. Like those on the south side, the mines have all been opened without capital, and their development depends entirely on profit. The writer believes that a proper system of crushing, sizing, and washing of the coal would result in its yielding a coke which would drive the English article out of Australia. Very few of the north-side mines are connected with the railway, and depend entirely on river transit.

The produce is taken down the river in punts carrying 100 tons to 150 tons. The river transit is, moreover, much cheaper than rail transit, the cost of the former being about 2s. 6d. per ton to put the coal on ship-board, whereas the cost to the south side mines is as follows:—Average railway freight, 1s. 6d.; wharfage, *i.e.*, putting the coal from truck into punts at Brisbane, 7d. per ton; puntage and putting the coal on ship-board, 2s. per ton; total, 4s. 1d. per ton.

The selling price ranges from 10s. to 11s. per ton for shipping. The inland trade is the most profitable when there is no puntage to pay. The reason of the puntage is that there is no export trade, the market being the bunkering of the coasting steamers, which usually stay only a few hours and take in coal while discharging cargo.

The mines are worked exclusively with naked lights, carburetted hydrogen being unknown. The only gas met with is carbonic acid and that in small quantities, which a good air-current easily removes. Furnace ventilation is universally adopted. The natural heat of the mines is great (the writer had not, it is true, any means of properly testing it), and the mine, 3 or 4 yards from the main air-current, however good this may be, is unbearably hot.

Mining accidents are not numerous. At West Moreton colliery, already referred to as the deepest in the colony, which has been working for three years, there has not yet been a fatal nor even a serious accident.

Underground Fire at West Moreton Colliery.

Fire had broken out underground before the writer took charge of this colliery, caused by the spontaneous combustion of the small coal; it was awkwardly situated, as it closed the best district, reducing the output

by 100 tons per day, and also rendered useless the second means of exit obtained by holing to the adjoining colliery. The fire was confined to one roadway, 40 feet above the level of the shaft, and the indiscreet way in which the workings had been driven, and the absence of a correct plan, rendered the matter of dealing with it one of difficulty. The means adopted were to take water from the surface, obtained from a cistern into which the mine water drawn by the cages was discharged; 2 inches pipes were taken underground to the scene of the fire, which could only be approached from the return side; a brattice was run up to convey air enough to enable the men to work, and the water was discharged through a nozzle on to the burning mass, which, as it cooled sufficiently, was filled away in skips and sent to the surface. Good progress was made in this way, and no doubt the fire would have been eventually subdued had not the heat and smoke, with the little fresh air which had to be supplied to the men at work, ignited the coal in another place in the return airway.

At this stage it was decided to seal up the district; in the absence of a plan of the workings, and, being a stranger in the pit, the writer was entirely dependent on the overman, who was the walking plan, to decide where the stoppings would have to be placed to exclude all air from the district. After investigation it was found that seven stoppings would be required, four in narrow places and three in wide bords; the same day the air was shut off by temporary stoppings of small coal in the wide bords and plastered wood stoppings in the narrow places. The presence of large volumes of black-damp rendered the work difficult, but all was made ready for the permanent stoppings of 9 inches brickwork and the erection was hastened as much as possible. No great difficulty was experienced until the building of the last stopping, which was 15 yards long, all the material for which had to be hauled 100 yards by a windlass up a gradient of 1 in 3. At this point large quantities of black-damp began to percolate through the temporary stopping, and all available air had to be conducted to the face of the work to enable the men to work even for short periods. It was, however, successfully completed, and after the mortar had dried and the brickwork was re-pointed, not a particle of black-damp could be detected.

It was the writer's intention, after a lapse of twelve months, to endeavour to drain off the black-damp and re-enter the district, but the financial condition of the company prevented him from being there to carry out the operation. The writer knows that the stoppings held good and that no further trouble was experienced from the underground fire.

Sir LOWTHIAN BELL, having to leave at this stage, Mr. W. COCHRANE took the chair, and invited discussion on the paper.

Mr. T. E. FORSTER said he was perhaps the only person in the room who had been down a colliery in Queensland, and his experience did not include the Ipswich coal-field described in the paper, the one he had visited being that of the Burrum river. He would reserve any remarks he might have to offer until he had an opportunity of reading the paper carefully.

The discussion was then adjourned, and a vote of thanks was accorded to the writer of the paper.

Mr. R. A. S. REDMAYNE read the following paper on "The Geology and Coal-deposits of Natal":—

THE GEOLOGY AND COAL-DEPOSITS OF NATAL.

By R. A. S. REDMAYNE.

Introduction.

After a residence of about nineteen months in this interesting colony, during which period the author prospected several properties and traversed the greater part of Natal from south to north and east to west, he ventures to record the results arrived at and opinions formed regarding its geology during his stay. He also desires to express his appreciation of the courtesy of his late directors in permitting him to read this paper, and to acknowledge his indebtedness to his friends, Dr. Sutherland, the ex-Surveyor-General of Natal; Captain G. Nicholls, R.E., Her Majesty's Commissioner of Mines in Natal; and to Mr. Dumat of Pietermaritzburg, for much information kindly afforded.

Physical Features.

From the Drakensberg range the land descends by steep terraces and gentle slopes to the sea-level. Natal, in fact, may be regarded as comprising three distinct plateaus, and as having corresponding variations of climate and production. These are: (1) the low-lying riviera extending inland for 15 to 20 miles, which is semi-tropical, producing tea, sugar, a little coffee, bananas, etc.; (2) the midlands, which are cold in winter, (Pietermaritzburg being regarded as the representative town): here oranges and vines flourish; and (3) the uplands, forming the chief grazing-grounds for sheep, cattle, and horses. This country is nearly destitute of trees, and is known as the "winter veldt," for the Boers bring their sheep and goats down in winter from the high veldt of the Free State to graze them in this, the warmer country. Ladysmith and Newcastle are the chief towns of the upland district.

The colony is divided into nine counties (Fig. 1, Plate XXII.), four of which, Victoria, Durban, Alexandra, and Alfred, are on the coast. The country is full of valleys and hills, and, although there are numerous watercourses, many of which, it is true, contain very little water in the dry or winter season, there is no navigable river.

The peculiar flat-topped or table-like mountain is a very characteristic feature of the Drakensberg range, and is due to the doleritic outflows which cap the mountains and preserve them from denudation. Many of the perpendicular precipices, or "krantzes" are of the same formation.

Geological Sketch.

So far as the writer is aware, no general geological map of Natal has been constructed, nor has any geological memoir been compiled—if we except that brief, though admirable, little pamphlet read by Dr. P. C. Sutherland, the ex-Surveyor-General of the colony, before the Natural History Association of Natal in June, 1868.

Alluvial Deposits.

Commencing with the most recent formation, viz., the alluvial, there is in the promontory known as the Bluff, at Durban, on which the lighthouse stands, a raised sea-beach, which is 300 feet above sea-level. It consists entirely of sand and broken shells. The writer has been informed that many parts of the coast are of similar character. There can be no doubt that the area next the coast (shown in the section, Fig. 2, Plate XXIII., kindly given to the writer by Dr. Sutherland) has been recovered from the Indian Ocean, the waves of which at one time beat against the Berea Ridge, on which are now situated the charming suburban residences of the Durban merchants.

The solvent power of water containing carbonic acid gas is well demonstrated by the accumulation of nodular limestone which segregates in the soils in many parts of the colony. In the Tugela Valley (as Dr. Sutherland informed the writer) there are masses of this species of limestone several hundred tons in weight. It is the excess of the carbonic acid gas that dissolved the lime out of the original rock, and upon its escape the lime was deposited as a carbonate. Bog iron-ore, or limonite, so very common all over the colony, has also been deposited in like manner. The limestone and the iron-ore are, however, too impure to be of commercial value.

Tertiary System.

No portion of the Tertiary system is represented in Natal. It may be that the fossil wood so abundant along the Drakensberg range is of this age, but that is an unsolved problem.

Cretaceous System.

The first formation of any importance found in descending order is the Chalk, which is seen on the sea-coast at the mouth of the Impengati river

in Alfred county, and at the mouth of the Umzumbe river, about two miles south of the Umtamvuna; some of the ammonites found in this formation are of considerable size. Large collections of fossils are to be seen in the Durban and Pietermaritzburg museums. Numerous magnificent forest-trees, some of which are 70 feet in length and 2 feet in diameter, are also found; their cavities are filled with flint, a characteristic feature of Cretaceous deposits throughout the world. These Chalk deposits consist of greenish sands and clays with rolled pebbles, derived from the older rocks, the cementing-matter being calcareous.

The greatest elevation of the Chalk above the sea does not exceed 100 feet. In no place has the formation been traversed or interrupted by intrusive dykes or outflows, a fact worthy of note in a country so scarred with igneous intrusions.

Oolitic System.

The Oolitic system is absent from this part of the African continent, for between the Umtamvuna Chalk and the coal-formation no intermediate features are found.

Triassic or Coal-measure System.

The Triassic system is the carboniferous or coal-measure formation of Natal, and probably of South Africa generally. Commencing at the surface in the interior, there is a gritty sandstone lying in nearly horizontal layers, and alternating with various coloured shales of differing thicknesses. The maximum thickness of the series is probably not more than 4,000 feet. Dr. Sutherland considers that the rocks found on the top of the Town Hill at Pietermaritzburg form the base of this formation (and judging from personal observation the writer agrees in that view); thence the series rises to nearly the summit of the Little Drakensberg, which is over 7,000 feet high.

On the surface of this formation is found the fossil coniferous wood, which appears to be the same as that found in the Cretaceous deposits of the colony. The area over which this formation extends is enormous: from the Town Hill, Pietermaritzburg, to the Drakensberg range, and thence to the Orange Free State and the Transvaal.. It forms also a narrow strip in Victoria county from the Umgeni to Compensation.

One of the most remarkable features of this formation is the number of igneous dykes and outflows which intersect and cut up the series. A very good example of this is found in the Zwartkop mountains; it may be traced (through a series of outbursts) into the Great Drakensberg, where it forms the weatherworn peaks, which rise to a height of nearly

10,000 feet above the sea-level. These dykes vary from a few inches to many feet in thickness, and may be many times repeated in a short distance. At the Howick falls (Umgeni river) near Pietermaritzburg, three distinct beds of greenstone are to be seen, separated by intervening beds of sandstone and shale.

The localities in which coal has been found are shown on the map of the colony (Fig. 1, Plate XXIII.); workable seams are, however, only found and worked within the shaded area in Klip river county. At the present time prospecting and borings are being made in the strip of coal-measure formation found in Victoria county, but from the facts and information so far to hand it does not appear that anything like a workable seam of coal has been or is likely to be discovered. The writer is, however, of the opinion that workable coal may possibly be found near the Drakensberg mountains, due east of Pietermaritzburg (Appendix A).

Mr. T. Bain and Prof. Seeley state in their report on the Geology of Cape Colony:—"At Cyphergat and Fairview, in Molteno, we obtained evidence that the fossil ferns and other plants which are found in shale immediately above the coal, are identical with those which occur in the same position in the Indwe coal-field," and that they also found remains of trees standing erect as they grew about the coal of Cyphergat, "thus demonstrating that the coal occurs in the position in which it grew."

After careful perusal of Mr. Galloway's report of 1890 to the Cape Government, and Prof. Green's paper of 1888, one cannot but come to the conclusion that the coal is of subaqueous origin. From the accounts given of Cape Colony coal-fields one cannot but be convinced that they are also contemporaneous with the Natal formations. The reasons advanced to prove the Natal coal-fields of subaqueous origin, are:—

(*a*) Fossil-remains are exceedingly scarce either just above, below, or in the coal. At Boston mills there is a 9 inches seam of coal resting on a bed of shale, in which roots of coal-plants are constantly found; and the roof, also shale, contains numerous leaves of coal-plants; while at a few other places, viz., Estcourt, Weston, on the Mooi river, and Lennoxton plant-remains are found, but as a general rule they may be considered as extremely rare. The finding of fossils in a few isolated cases does not militate against the subaqueous theory.

(*b*) The extraordinary variations in the thicknesses of the seams of coal in a very short distance: in one case thinning out to 1 foot and in a few yards increasing to 3 feet, and again in the same distance thinning out again. The wavy and false-bedded nature of the strata immediately above and below the coals, and the great variation in the thickness and

character of the bands separating the coal, as well as the ripple-markings, so common in the sandstone or shale just above and below the seam, are further proofs of the origin of the deposits.

(*c*) The total absence of any underclays. The floor of the seams being usually sandstone, and sometimes a shale-bed.

(*d*) The instance mentioned by Dr. Sutherland, where, in the Newcastle district, there was found embedded in the coal a fragment of granite, which weighed about 1½ lbs., goes further perhaps than anything else, to prove these coals to be drift material. Dr. Sutherland himself, however, does not bind himself to any theory.

(*e*) The specific gravity of the coal is high, showing the presence of earthy impurities, which is borne out by chemical analysis, and on very close examination thin layers of earthy matter are observable in some of the coals.

The most characteristic fossil of the few found in the coal-measures, is *Glossopteris*, which is eminently a Triassic fossil. No remains of *Stigmaria* or *Sigillaria* have as yet been discovered, and the writer has only seen one specimen of *Lepidodendron* (found near Newcastle, S.A.).

Pietermaritzburg Shales.

Below the sandstone and Carboniferous shale formation, referred to above, come the Pietermaritzburg Shales, which may be taken as contemporaneous with the Kimberley or Olive Shales (described by Prof. Green in his paper). This shale-formation, which is found all over Pietermaritzburg, can be traced without a break nearly up to the summit of the Town Hill. No indications of plant or other reliable fossil-remains are found in it. These beds may be regarded as representing the Middle Trias.

*Boulder-clay Formation.**

The Pietermaritzburg Shales pass downward into a very curious formation of breccia, which has, so far, proved the *bête noir* of South African geologists. It is composed of a greyish-blue argillaceous matrix, containing numerous fragments of igneous rock; these vary greatly in size, some being very large, weighing upwards of 5 tons, uniformly dispersed throughout. Dr. Sutherland says "It passes on one side only into the Pietermaritzburg Shale, and on the other it abuts upon the next succeeding formation underneath, upon which it appears to rest." The included fragments of rock have the appearance of being smooth and polished by attrition.

* The Boulder-clay formation is a very misleading term for a Palæozoic group, and the author regrets that he is compelled to make use of it.

Dr. Sutherland calls it the Boulder-clay formation. Mr. Dunn describes a similar deposit in Cape Colony, which he names the Dwyka Conglomerate; Mr. Bain, the Claystone-porphyry; and Mr. Wyley, the Trap Conglomerate, meaning thereby that it is of volcanic origin, which is by no means certain.

Prof. Green admirably describes the rock as it occurs at Grahamstown (Cape Colony), and his description tallies exactly with the character of the Natal deposit. He speaks of it as "a dark-grey, closely-grained, hard matrix, thickly set with many small angular fragments and rounded grains of quartz, the larger included blocks not very numerous, the majority angular and subangular, but some well-rounded pebbles . . . . a whitish granite, rich in quartz, was by far the commonest rock among the fragments, but quartzites and other rocks occur. In many places no bedding is discernible, but where the rock has been exposed it has a bedded look . . . . The matrix of the rock" he adds "has all the look of mashed-up granite mixed with fine mud." Although Prof. Green says "the size and angularity of the boulders suggest the action of ice," he leans to the opinion that it is a lacustrine deposit. Dr. Sutherland, in a letter to the writer, says "There can be no doubt that the formation in question had its fringe exposed to the action of water. At the point where it passes into the shale it is in many parts ripple-marked, which is clear proof of its exposure to the action of water subject to oscillation of the surface with regard to the beach, as well as back-and-forward motion. These ripples are best seen at Umzinto, where good puddingstone is won from the formation at the line of its passage into the shale."

The area over which this formation extends is very great. It is found throughout the northern part of Victoria county; it flanks the sandstone hills on their seaward side from the Tugela river to the Umgeni river, and occupies both sides of the Umgeni river at Queen's Bridge; it passes south through Cato Manor and the Berea, and crops out at the sea-level at the Umbilo, near Congella. It is further to be found extending as far as the St. John's river. On the other hand, it is found cropping out extensively in the vicinity of Pietermaritzburg, between Greytown and the Biggarsberg mountains, and many other places.

The equivalent of the Old Red Sandstone is wanting in Natal.*

Silurian System.

Below the breccia we pass into a sandstone of Silurian age. These Silurian rocks occupy the flanks and hollows of the primitive rocks on

* The author is inclined to think that the Dwyka Conglomerate represents a part of the true Carboniferous system.

which they rest horizontally and much faulted. In many parts they contain numerous rolled, polished fragments of quartz derived from these older rocks. The thickness varies up to 500 feet in Natal, though it is found much thicker in other parts of South Africa. Table Mountain (near Pietermaritzburg), Inanda, and Izwate are instances of it.

Pre-Silurian Rocks.

The primitive rocks, consisting of granites, mica-schists, clay-slates, and marbles, are seen in the gorges of the mountain-valleys, and at Bishopstowe, close to Umsumdusi river. The series extends northward through the Inanda location into Zululand, following the deep valley of the Tugela river. At the Lower Umzimkulu river, about 6 miles from the sea is found a mass of metamorphosed limestone, forming a marble of great purity, but too highly crystallized for statuary purposes. This deposit is of very considerable extent, having been proved to exist over 35 square miles, and it is not less than 1,200 feet thick.

Summary.

The following classification of the Natal rocks may, the writer thinks, be adopted, and is shown in correlation with Prof. Green's division of the Cape Colony rocks:—

Natal.	Cape Colony.	
Alluvial	Alluvial.	
Cretaceous	Cretaceous.	
Igneous rocks, dykes, and outflows, capping the Drakensberg range ...	Volcanic beds.	Stormberg beds.
Coal-measures (Triassic)	Cave sandstone.	
	Red beds.	
	Molteno beds.	
	Karoo beds.	
Pietermaritzburg Shales	Kimberley Shales (great unconformity).	
	Ecca beds.	
Boulder-clay	Dwyka Conglomerate (great unconformity).	
Silurian	Quartzite.	
	Bokkveldt beds.	
	Table Mountain sandstone.	
Pre-Silurian (gneiss, granite, marble)	Slates and intrusive granite (Malmesburg beds).	

The Northern Coal-fields of Natal.

It has been shown that coal undoubtedly exists in many parts of Natal, but readily workable seams occur only in the Klip river district.

Mr. F. W. North, commissioned by the Government of Natal to prospect the coal-fields of the colony, reported thereon in September, 1881. His report undoubtedly led to the erroneous notion of the existence in the Klip river district of an extensive workable coal-field abounding in outcropping coal-seams "invariably situated in favourable positions for economical working."

In reality, the coal-deposits in Natal are spread about in beds of coal of variable quality of no great extent individually, and often reduced by erosion. In the Klip river district, for instance, coal-seams outcrop over a country of about 1,190 square miles, but this very considerable area is no gauge of the workable coal-beds. The assertion of their being invariably situated in favourable positions for economical working is disposed of, when the aspect of that broken country is considered.

Since the issue of Mr. North's report, the Natal Government Railway has been completed to the frontier of the Transvaal. (Fig. 1, Plate XXIII.) Laterally to the line, but only within the limits of a comparatively narrow belt where branch-lines can be constructed at reasonable cost, has the coal country been opened out; otherwise it remains as inaccessible as ever. Any other railway through it, if ever constructed, will be attended with similar limited advantages.

The belt of coal-bearing lands along the railway line from Elands Laagte to Newcastle (Fig. 1, Plate XXXIII.) can be divided into three parts:—(*a*) south of the Biggarsberg range, (*b*) the Dundee plateau, and (*c*) the Newcastle district.

Biggarsberg Coal-field.

In that part south of the Biggarsberg range and nearest the seaport, the apparently promising coal farms were hurriedly taken up in expectation of immense financial profits, were partially developed, and subsequently nearly all abandoned, owing to the inferior quality of the coal, the thinness of the seams, or the impossibility of connecting them to the main line of railway at a cost in proportion to the importance of the mine; and unless some improbable circumstance intervenes they are not likely to be re-opened.

A brief description, however, of these mines may not be out of place.

(1) *The Elands Laagte Mine.*—This was one of the first mines which produced coal in the colony. During the year 1889, 19,094 tons were raised, and 7 Europeans, 2 Indians, and 100 natives employed. But in 1890–91 the output fell to 7,334 tons, and the mine has now ceased working. The coal supplied from it had no very good reputation in

the colony, owing to its high percentage of sulphur, and its being put on the market in a dirty condition.

(2) *The Natal Colliery.*—The output from this colliery for the year 1889 was 2,206 tons, the labour employed consisting of 2 Europeans and 18 natives; the output in 1890–91 was only 373 tons. It is now closed.

The section of the seam was as follows:—

	Ft.	Ins.
Sandstone-roof.		
Coal	2	2
Shale-band	0	9
Coal	1	4
Sandstone-floor.		

The Shotts colliery, a small mine, was opened on a portion of the Natal Colliery Company's property, the coal produced from it (in 1891) being 142 tons.

(3) *The Ramsay or Inkunzi Colliery.*—The writer spent some time at this mine, over which he was conducted by the then manager, Mr. Tylor, who was at one time a member of this Institute, and who served a portion of his apprenticeship in Northumberland. The writer can safely say that it was the only properly laid-out and best managed coal-mine in Natal.

The seams of this neighbourhood are mentioned by Mr. North on page 29 of his report, and shown in his sections 54A and 55. The writer obtained the following section from Mr. Tylor:—

	Ft.	Ins.	Ft.	Ins.
Sandstone, increasing in thickness as the hill rises.				
(1) Not worked—				
Coal	3	0		
Shale	1	6		
Coal	1	0		
Sandstone, false-bedded, solid above shale	20	0		
Shale	2	6 to	4	6
(2) Worked—				
Coal	1	8		
Parting	——			
Band (average 2 inches)	0	1 to	0	6
Coal	0	8		
(3) Not worked—				
Sandstone...	12	0 to	18	0
Coal	1	0		
Splinty coal	0	6		
Sandstone.				

The mine is worked by drifts or adits driven in the coal which crops out near the base of the hill. There are dykes in the vicinity of the mine, but none of these have been passed through, for the workings have not proceeded far enough as yet.

The coal being worked was more like good North-country (Durham) household coal than any the writer has seen in the colony; it is also more bituminous than most of the Newcastle (Natal) coals. When the writer visited the mine it was being worked on the longwall system, by far the most suitable method of working a seam of this nature; the shale-roof being ripped down in the gateways to make tub and travelling-height. The squeeze or subsidence was very even, and closely followed the advancing workings. The surface appeared to be in no way damaged.

The seam was kirved just above the band, the top-coal being wedged down and the bottom-coal wedged up. All hewing and transport was performed by 24 Kafirs, the only white man being the manager. The hewers worked from sunrise to sunset, with intervals for meals amounting to two hours in all, and were paid at the rate of £2 5s. per 30 working days, with rations (in addition) of mealie meal, and meat once a week. The night "boys," who rip down the shale for height, worked 14 hours with no allowance for meals, and received 5s. per month (30 days) more than the hewers. The cost of working and conveying the coal to the mouth of the adit was 7s. per ton, on an output of about 15 tons per diem.

The output for 1889 was 2,500 tons, and from July, 1890, to 30th June, 1891, 4,704 tons were worked. The coal was conveyed to the Natal Government Railway, 3½ miles distant, in Scotch carts drawn by oxen in summer and by mules in winter. The cost of transport being 3s. per ton.

The mining rights were leased from one of the Amakowlwar Kafirs (Christians), who own and farm the land in this district. This mine has recently been closed.

(4) *The Acol Colliery.*—The seam worked, which is of the following section, corresponds to the upper or No. 1 Seam of the Ramsay mine:—

	Ft.	Ins.
Sandstone-roof.		
Coal	1	10
Shale	0	8
Coal	1	4
Sandstone-floor.		

During 1889, 600 tons were worked, and the output increased during 1890-91 to 4,235 tons; but very little, if anything, is being done at the mine at the present time.

(5) *The Wallsend Mine.*—The Natal Government Railway passes through this property. The section of the seam worked was:—

	Ft.	Ins.
Sandstone-roof.		
Shale	1	9
Coal	1	10
Shale	2	5
Sandstone-floor.		

The output for 1889 was 184 tons, and in 1890-91, 2,000 tons; the labour employed being 7 Europeans and 70 natives. The coal on this property is extremely good, and the best results were obtained from it when it was used on the Government Railway; but owing to the thinness of the seam, the cost of working it was too high to allow of the carrying on of the mine at a profit, and it ceased working in 1891.* Recently, however, the Uithoek, a small mine, has been commenced in the northern part of the farm.

The Dundee Plateau.

North of the Biggarsberg range is the Dundee plateau. Here the successful Dundee colliery (11,000 acres, capital £110,000) has absorbed a great part of the workable coal-beds of the neighbourhood, and the St. George's Company contemplate starting, some miles to the north. That company having, the writer understands, completed the necessary survey and proved their property.

The Dundee Colliery.—The writer several times visited this, the premier mine of the colony, the workings of which he surveyed for the Natal Government Railway authorities. The following is an average section of the seam worked:—

	Ft.	Ins.
Sandstone-roof (firm).		
Coal	1	2
Shale (taken down to make height in main roads)	0	3
Coal (worked)	4	8
Shale	0	4½
Coal	1	10
Sandstone-floor.		

There are three shafts, coal being drawn from two of them.

The seam lies at a depth of 60 and 70 feet in the two working shafts, respectively, the superincumbent stratum being sandstone, which reaches to the surface. The shafts are fitted up with rail-guides and single-decked cages, capable of holding two 10 cwts. tubs. The drawing is performed by two small Robey winding-engines. The mine produces a quantity of water, which is raised to the surface by a small double-acting Tangye force-pump.

The workings are laid out and conducted on the old-fashioned bord-and-pillar system. The pillars or stoops are very small (5 by 3 yards). The galleries average about 4 yards in width. Little or no use seems to have been found for the slack or small coal which lies in large heaps about the surface.

* The writer is informed that the mine has recommenced working.

One of the main roads is driven through a large dolerite dyke, the coal in its immediate vicinity being much burnt, but very little disturbed. The writer observed this latter peculiarity throughout the coal-field.

The mine is connected to the Natal Government trunk-line by a single line 7 miles long, which, although laid over a level country, with few impediments in the shape of spruits or dongas, cost about £58,000. The Government are taking the line over from the company at the same price, the payment being spread over five years.

When the writer visited the mine in August, 1891, there were employed 24 Europeans, 140 natives, and 35 Indians, and the output amounted to about 3,500 tons per month. The company now employs about thrice as many natives, and raises about 10,000 tons per month.

On the commencement of removal of the pillars in 1892, a large subsidence of the surface took place.

Cartridges of gunpowder mixed with sawdust are used for bringing down the coal, they are ignited by means of fuse. The kirving is made in the coal. Candles are used by the miners (2 tons per month), but the electric light is in course of being installed at the shaft bottom and in all the main roads. A ventilating-fan is also being established at No. 3 shaft.

The cost of working at this colliery in the year 1890, according to Mr. Hallimond (the then manager) was under 5s. per ton.

The wages for Europeans varied, and depended on the character of their work; so far as the writer can remember them, they were as follows:—Overmen, £16 to £20 per month with free house and coals. Other white labour, from £10 to £14 per month. Kafirs, £1 10s. to £1 15s. per 30 working-days with mealie-meal rations and meat every Saturday. Corrugated-iron barracks are provided for the natives to sleep in. The Indians, who are employed about the surface, are paid a somewhat lower wage than the Kafirs, and receive, by way of rations, rice and dohl (dried fish). Masons' wages are very high, and most of their work is done by contract.

Newcastle District.

In the Newcastle district there are, within easy distances from the main line of railway, working and workable coal-deposits of very considerable value, and it is the writer's belief that the district will eventually prove to be the chief source of coal supply for South Africa; at any rate until the Zululand coal-deposits are worked.

Fig. 3, Plate XXIV., shows the relative positions of these properties and their proximity to the Natal Government Railway.

The Southern Cross, Newcastle colliery, and Rooi Pont estates have been proved, partially developed, and are working. The Ballengeich farm has been proved by borings, discovery of outcrops, and a shaft has been sunk. The Braakfontein, Tiger Kloof, and Leicester farms, and two blocks of Government land (42 and 111) all contain sufficient indications of coal to justify the expense of proving them.

The other coal-bearing farms of the district, including some of the Government lands, have not been considered, either by reason of the bad quality of the coal, or the impossibility of connecting them with the main line of railway at a cost in proportion to their present importance.

The writer believes that the amalgamation of these properties under one colliery and land company, with adequate working capital, would, for a long time, have rendered the formation of any new parallel operation at least improbable; and, perforce, would have made them the sole competitors of the Dundee collieries for supplying the local and export trade.

(1) *The Southern Cross Colliery.*—This company possesses four blocks, I, J, K, M, of the Newcastle town lands.

Fig. 4, Plate XXIV., shows the configuration and area of the property, the position of the boreholes and of the shaft, by which the seam is now worked, and the position of the outcrop on the left bank of the Ingagane river. The sections of the several boreholes are noted in Appendix B.

The following is a detailed section of the upper seam now being worked, chiefly for household purposes :—

	Ft.	Ins.
Black-shale-roof	1	0
Splint	0	7
Coal	2	3
Sandstone-band	0	1
Shale-band	0	3½
Coal	0	1
Splint	0	6
Coal	0	7
Splint	0	3
Coal	0	3
Splint	0	2
Coal	0	6
Total thickness	5	6½

According to the borings, the coal extends in workable thickness over at least 273 acres in the upper seam at a depth of 54 feet, and over an equal area in the lower seam at a depth of 81 feet. The average thick-

ness of the seams can be reckoned at 3 feet 5 inches, and after a deduction of 5 per cent. for loss underground, there will be 1,200,000 tons of available coal in each seam, of which three-fourths may be reckoned as round coal and one-fourth as small coal and dust.

Samples of the coal have been analysed by the chemist of the South African Trust and Finance Co., Ld., of Johannesburg, showing:—

Moisture	1·91 to	2·27
Volatile products	34·49 „	36·73
Fixed carbon	51·55 „	53·06
Ash	10·80 „	6·98
Sulphur	1·25 „	0·96
Coke	63·60 „	61·00

Dr. A. Simons, of the Ferreira Gold Mining Company of Johannesburg, analysed samples with similar results, and to his report he adds:— "The coal will yield a coke capable of competing with the best imported coke. It is a good household and good steam coal."

It was tested by the Johannesburg Lighting Co. at the request of Dr. Simons. They reported a yield of 11,000 cubic feet of gas and nearly 14 cwts. of coke per ton of coal (2,240 lbs.); the illuminating power of the gas burnt in a standard argand burner, burning 5 feet of gas per hour, was found to vary between 17·51 and 17·54 sperm candles.

A train weighing altogether 119 tons ran from Durban to Botha's Hill station, 31¼ miles, reaching an altitude of 2,425 feet, the steepest gradients being 1 in 30, in 2 hours 41 minutes, on a consumption of 17 cwts. of coal. No difficulty was experienced during the run in keeping the steam pressure at 130 lbs., the engine reaching its destination under full pressure, and it could have run 6 miles more. Finally, on cleaning the fire-box there was very little clinker, and scarcely any ashes in the smoke-box.

The mineral rights are held under the Corporation of Newcastle for twenty-one years at a yearly rental of 5s. per acre, and a royalty of 3d. per ton of coal raised. The company is endeavouring conjointly with the Newcastle Colliery Co. to have their leases extended, and otherwise modified in terms of the regulations for mining on Crown lands; this means that the royalty mitigating the rent, the royalty of 3d. per ton raised will finally be only chargeable against the coal. The Newcastle Corporation offering no opposition, it is only a question of legal *modus operandi*, subject to the sanction of the Government (which has now been obtained).

The colliery is 1¾ miles distant from the Natal Government Railway. The branch line over an easy country has been surveyed, necessitating only 9,775 cubic yards of excavation, earth and banks, and 124 yards of concrete and masonry.

(2) *The Newcastle Colliery.*—The company possess three blocks N, O, P, of the Newcastle town lands.

Fig. 4, Plate XXIV., shows the configuration and area of the property, the position of boreholes, and of the adit by which the seam is now worked. The following is a detailed section of the working seam :—

	Ft.	Ins.
Sandstone-roof, hard and firm.		
Coal	2	6
Splint-band...	0	6
Coal	0	4
Band, variable	0	3
Coal	1	0
Band, variable	0	3
Coal	1	2
Total thickness	6	0

Judging from the contour of the surface, and the lie of the seam, coal extends over the whole area of the property, and deducting this from the area already worked, there remains 270 acres of coal of an average thickness of 4 feet 3 inches, containing, say, 1,814,940 tons of available coal, of which one-fourth will be nuts and dust, and three-fourths will be round coal.

It is extremely probable that the two seams will be found existing on the Southern Cross property, but in the absence of sufficient boreholes and surface-levelling, it is only a possibility; therefore the estimate of available coal in this estate is limited to the tonnage given above.

The remarks as to the quality of the coal of the Southern Cross colliery equally apply to the coal of the Newcastle colliery, both being the best Natal coal.

This company has a nominal capital of £20,000, of which £12,800 is paid up. The mineral rights of the estate is held for twenty-one years, from the Corporation of Newcastle, at a yearly rental of 12s. 8d. per acre, and a royalty of 3d. per ton of coal raised. The mine is connected to the Natal Government Railway by a 2 feet gauge light tramway of portable type. The present output is about 40 tons daily.

Several blocks of the Newcastle town lands have been marked by the corporation on the assumption that the Southern Cross and Newcastle colliery seams are represented therein, but a portion only, however, will be coal-bearing.

Lennoxton Mines.—These mines are situate north-west of Newcastle, but both of them are now closed, and are too far removed from the Natal Government Railway to be of importance in the near future.

Braakfontein Farm.—On this farm, on the right bank of the Ingagane river, lies the same coal-seam as that found in the Newcastle town lands, on the opposite bank, the coal cropping out on both sides. The farm is unproved, but all the indications, however, are most favourable.

Rooi Pont Farm.—The area of this farm is 3,043 acres. Its position is shown on Fig. 3, Plate XXIV. The eastern half of the farm is much cut up by kopjes (or craggy hillocks), having very steep sides. The summits form elevated plateaus covered with good grass. From careful observation the writer came to the conclusion that the portion of the farm lying east of the Natal Government Railway (low-lying land) must be regarded as containing no coal, which leaves 1,650 acres; over the greater part, if not the whole of this area, the seam will be found to exist.

The seam has been proved by a shaft sunk to a depth of 28 feet on the side of the kopje, and by an adit. A section, east and west, across the farm is shown in Fig. 5, Plate XXIV.

An average section of the seam is as follows:—

	Ft.	Ins.
Sandstone	——	
Shale	——	
Coal, bright and cubical	2	0
Band, with strings of coal	0	5
Splint-band...	0	5
Coal, bright and cubical	0	6
Band	0	3
Coal, bright	0	4
Band	0	2½
Coal	1	0
Total thickness	5	1½

Taking the average coal section at 3 feet 8 inches, there will be 6,016,000 tons of workable coal. The coal described as bright and cubical is a glossy friable coal, splitting up into small cubes, and more of a bituminous than an anthracitic nature.

The property is owned, and was being worked when the writer was in Natal, by Mr. Draper, an old colonist.

Tiger Kloof Farm.—This farm (Fig. 6, Plate XXIV.,) had originally an area of 3,978 acres, but the Natal Government Railway cutting through it reduced it to 3,953 acres. There are sufficient indications of coal to

justify the expense of proving it systematically, which is now being done. A shaft on the northern boundary of the farm, by which the seam was for some time, twelve years ago, worked for local sale, has now fallen in; but, according to a miner, it showed a section of 5 feet of coal.

On the south-eastern corner of the farm is an outcrop through which the Natal Government Railway passes. The existence of sections of 5 feet of coal in the northern and southern extremities of the eastern portion of the farm, coupled with the fact that the surface rises toward the kopjes on the west, is a fair proof of the existence of coal on that portion of the farm from the railway to the western boundary.

The kopjes being formed by an outflow of trap rock that can be traced to a point of eruption on the Natal side of the Drakensberg, it is not probable that the coal underneath has suffered any serious disturbance. Coal, then, may be said, with sufficient accuracy, to exist on two-thirds of the property with a workable section of 5 feet, and, after deducting for loss in working, containing 20,000,000 tons of available coal. Among the great advantages of this property is its accessibility to the Natal Government Railway, requiring nothing more than a short siding, and the fact that the coal can be approached and mined by adits.

The Ballengeich Farm.—Fig. 3, Plate XXIV., shows the relative positions of this farm, and of the Natal Government Railway, with the Ingagane river between them.

Fig. 7, Plate XXIV., shows the Horn river, an impetuous torrent, often flooded in the rainy season, flowing nearly at right angles to the Ingagane river, the consequence being that when the Horn river is flooded it dams the Ingagane river and causes it to overflow its banks, the flood covering the lowland on the left bank, across which the branch line would have to be constructed. A substantial viaduct, 600 feet long, would be required, entailing an outlay of £18,000 for bridge and railway. The connecting of the contemplated colliery to the railway could be accomplished at a smaller original cost by a rope (aërial) tramway, but such a mode of transport would unavoidably be attended by contingencies that might ultimately prove very serious.

The outcrops of coal are denoted by the letters *a*, *b*, *c*, *d*, *e*, and *f* (Fig. 7, Plate XXIV.). At none of these points is the seam shown in its full height, as all the outcrops are injured by exposure to atmospheric agencies, and a reliable section could not be obtained without excavating for some distance. Mr. North made an excavation at the point *e* as follows:—

	Ft.	Ins.
Hard coal	1	0
Grey shale	0	3
Coal, hard	3	8
Arenaceous shale	0	6
Dark grey sandstone, very hard	0	6
Coal	0	5
Shale and coal	0	6
Coal	0	8
Parting	——	
Coal	0	8
Parting	——	
Coal, hard and good	2	1
Sandstone	0	3
Coal, good	1	0
Parting, with iron pyrites	0	1½
Coal, good	1	2
Total thickness ...	12	9½

Although this section shows a considerable thickness of coal, it at the same time shows a large number of bands, a very serious item, when the working and screening of the coal is considered. This may be taken as an average section of the main seam over the farm.

The outcrop at *d* is of two small adjacent seams, lying at some height above the main seam, and shown in section of No. 3 borehole (Appendix C); these, however, owing to their thinness, are, of course, of no value, except as evidence of the regularity of the strata. The strata overlying the main seam are far more regular, as regards character and thickness, than was observed on other farms in the neighbourhood.

Boreholes, Nos. 5, 6, and 7, were put down on this farm. No. 7 hole, drilled near the shaft, went 90 feet down, coal was found at 48 to 60 feet and was analysed. In No. 5 hole, drilled near the Kafir kraals, coal was found at 41 feet 6 inches, then 6 inches shale-band, 52 feet to 55 feet coal again, the roof being shale and the floor sandstone.

The other boreholes, one of which was put down near Mr. Degenaar's house, struck whinstone, whether a dyke or outflows from a dyke is unknown.

The shaft is 43 feet deep, and is sunk through the seam, where, according to Mr North, there is 9 feet of coal.

No. 1 borehole (Appendix C) is situate on the lowest ground, but it did not strike the seam, which had been denuded, in all probability, by the action of the Horn river. But, owing to the heavy dip of the seam to the south, the seam was struck in the No. 2 borehole (see Appendix C); the heavy dip may be due to faulting, which cannot be determined until underground development has proceeded somewhat. There is no external

evidence of faulting, and the difference of level of the seam in the shaft at the Horn river, and at Nos. 2 and 3 boreholes (Appendix C), is most probably due to dip alone; still, there may, however, be some small faults. Unluckily, the No. 4 borehole struck a whin dyke.

The order of succession of strata may be taken as follows:—

(*a*) Basaltic overlying formation, forming dykes and outflows, piercing and capping the kopjes.

(*b*) Laminated grey rock and thin bands of shale, and thin local seam or seams of coal.

(*c*) False-bedded sandstones.

(*d*) Laminated, arenaceous, micaceous, black and grey shales, with sometimes a band of sandstone forming the roof of the seam.

(*e*) Main coal-seam.

(*f*) Hard sandstone-floor.

The roof of the seam is in most cases composed of shale, which means an increased cost of working, and is very likely to be water-bearing.

In the section of the seam given by Mr. North, the coal is much more split up by bands than it is in the sections given by the boreholes, which makes it probable that the small bands of shaly matter have been passed through whilst drilling in the coal, and washed away (if there was any shale core) by the water pumped down to keep the diamond crown cool and the hole clean.

The tops and sides of nearly all the hills are covered with large whin (basaltic) boulders; and in places the bedded rock is visible. These kopjes or hills owe their existence and origin to this protecting cap of doleritic rock, which has shielded the underlying strata from the various denuding agents that have at one time carried away the original surface. This whinstone exists in two conditions or forms: (*a*) as dykes and (*b*) as outflows. (See Fig. 8, Plate XXIV.)

A considerable part of the hill-surface is formed by overflow whinstone, the dykes existing in a truncated form. It is very probable therefore that the seam will exist for a considerable distance beneath the hills, but whoever works the coal must expect to contend with a considerable number of dykes, which exist also in the lower part, but unaccompanied by outflows. The coal will be more or less indurated in the vicinity of these intrusive masses, and probably useless and unsaleable.

After allowing a liberal deduction for loss by denudation and dykes, there may be 2,800 (out of the 4,005) acres of workable coal, containing a total of 51,010,400 tons of workable coal and at least 38,257,800 tons of vendable round coal.

Mr. C. Hall wrote, in 1889, with reference to the coal from samples of cores from Nos. 5 and 6 boreholes:—"The coal is of fair quality, part anthracitic and part clear-burning bituminous coal, the latter with 22 per cent. of volatile matter and 14 per cent. of ash. It does not light easily, but once started continues to burn, giving out a steady heat as long as there is a good draught. The clear-burning part cakes slightly, but does not form clinker. The ash remains in friable lumps, retaining the original form of the coal." He considered, as far as he could judge from a small sample, that it was better suited for steam raising than for household purposes. The quality of the coal from No. 5 hole, so far as percentage of ash was concerned, was slightly better than the more solid coal.

Mr. E. Neville, Government chemist, wrote in 1891, respecting a sample of coal taken from a borehole on the Ballengeich farm. "It is a hard, compact, dull, greyish-black coal, with a specific gravity of 1·499, of the following composition:—

	Per Cent.
Moisture	1·68
Volatile hydrocarbons	10·84
Coke, free from ash	71·32
Sulphur	0·88
Ash	15·28

The coal is a semi-anthracite of good quality, containing a considerable percentage of ash, and yielding an amorphous coke. Mixed with a more bituminous coal and burnt with a good draught, it would be an economical coal for raising steam. Its small proportion of sulphur and the absence of phosphorus render it suitable for most metallurgical processes."

The Leicester Farm.—This farm, with an area of 3,956 acres, is situated in a favourable position on the right bank of the Ingagane river, the Natal Government Railway running through the estate for about 2½ miles (Fig. 3, Plate XXIV.). This property is not actually proved otherwise than by an out-crop on the right bank of the Ingagane river, close to the railway, and a trial shaft on the opposite side of the line. According to Mr. North, there is a seam of 8 feet 9 inches in thickness. In the absence of a detailed section, and judging from the coal lying at the mouth of the shaft, it is difficult to believe that he found the seam to have a clean section. On the contrary, judging from the samples lying at the surface, it is a hard splinty coal, showing a considerably less section of available coal. It is a hard, semi anthracitic coal, which ignited with difficulty, but gave out great heat when burning.

Lately the Commissioner of Mines drilled a borehole (Fig. 7, Plate XXIV.) which went to a depth of 324 feet without passing through any

coal-seam. The coal-bearing portion of this property must therefore lie south of the shaft and the outcrop, the contour of which is favourable to its existence.

RAILWAYS.

Over 375 miles of railways are open for traffic. The main trunk line extends from Durban to Ladysmith (189¼ miles), Biggarsberg and Newcastle (268 miles), and is now completed northward to Charlestown (304 miles) on the Transvaal frontier. There is a branch line from Biggarsberg to the Dundee coal-fields (which will ultimately prove the main line to Zululand) and from Ladysmith to Harrismith *via* Van Reenan's Pass into the Orange Free State. From Durban lines run northward to Verulam (19 miles) and southward to Isipingo (7 miles).

The railways are the property of the Natal Government. The greater part is laid over very difficult country, especially between Durban and Pietermaritzburg, and over the Town Hill, north of the latter town, and those parts which cross the Berg at Van Reenan's Pass, and Langs Nek below Amajuba.

The distance by wagon-road from Durban to Pietermaritzburg is 65 miles, and about 70¼ miles by rail. Some of the curves are extremely sharp. The steepest gradient is about 1 in 35.

The following figures will show the excellent management of this railway system:—

1886, 189½	miles open;	revenue,	£108,878.
1887, 216¾	"	"	257,877.
1888, 220	"	"	349,184.
1889, 241	"	"	535,261.
1890, 286	"	"	606,713.

For the financial year, ending June 30th, 1891 (taking the first six months of the year as a basis of calculation), the following results were arrived at:—

Gross income	£587,499
Gross expenditure	£356,957
Excess income	£230,542
Earnings per open mile	£1,882
Earnings per train mile	14s. 2·74d.
Expenditure per open mile	£1,144
Expenditure per train mile	8s. 7·72d.
Passenger earnings	£111,701
Goods earnings	£455,730
Miscellaneous earnings	£20,060
Interest on capital	£235,360
Proportion of expenses to earnings...	...60 per cent.

The proportion borne by working expenditure to receipts in some other countries may be usefully recalled by way of comparison:—In Great Britain it is 53 per cent.; in Cape Colony, 55 per cent.; in Germany, 52½ per cent.; in Austria, 54 per cent. for State lines, and 44¾ per cent. for companies' lines; in Belgium, 62 and 52½ per cent. for State and companies' lines; and in France, 90 and 50 per cent. for State and companies' lines.

The Harbour.

Durban is the only seaport of Natal, with a population of 25,000, of which one-quarter are natives and Indians. The business of the harbour has in past years been much impeded by a shifting bar of sand across the mouth of the channel.

The average depth of the channel at low water has, however, increased from 6 feet 1 inch in 1882 to 10 feet 9 inches in 1891, and the harbour works are still being continued at considerable cost to the Colony. The total sums paid out of the Treasury up to May, 1890, and used by the Harbour Board, amounted to £640,729.

The maximum draught brought inside in 1890 was 16 feet 8 inches and the mean draught 13 feet 8 inches. 118 steamers came inside during 1890 as compared with 114 in 1889, 68 in 1888, and 63 in 1887; 179 sailing vessels came inside during 1890 as compared with 196 in 1889, 165 in 1888, and 135 in 1887; the total increase in tonnage which has arrived at the port in 1890 was 11,937 over 1889, 133,327 over 1888, and 258,095 net tons over 1887.

There are as yet no proper facilities for shipping coal. The cost of coaling vessels is about as follows:—

	Per Ton. s.	d.
I.—Coaling alongside the wharf:—		
(*a*) When shoots can be applied	1	0
(*b*) When the steam-crane is used	1	6
(*c*) High boats, where baskets have to be adopted	2	0
(*d*) Sacking and trimming	0	6

II.—Coaling outside:—	Per Ton. s.	d.		
Putting into lighters	1	0		
Taking out of lighters	5	0		
Putting under hatches	1	6		
			7	6

The authorities have, however, under consideration the erection of hydraulic tipping-appliances, designed by Sir W. G. Armstrong, Mitchell, & Co., to suit the 20 tons trucks of the Natal Government Railway, which will greatly reduce the cost of coaling.

Present and Possible Future State of the Coal Trade.

The Natal coal industry is of course extremely young—in fact it may be regarded as not more than four years old. The unavoidably limited demand at the beginning of the industry has been a check on its development, but it now exceeds the supply.

On that question, as well as that of transport, His Excellency the Governor expressed himself at the opening of the Legislative Council on the 5th of May, 1892, as follows:—"The supply of coal for export is assuming such proportions that it will probably be necessary ere long to take into consideration the possibility of increasing the carrying capacity of our railway."

There are so many stations on the Indian Ocean where a considerable tonnage of coal is actually supplied at higher prices, and in no better quality than procurable from Natal, and where it will be permanently required, that it is a natural inference to say, as above, that the demand for Natal coal will be limited only by the ability of their collieries to supply it.

The present import duty on all coal or coke entering the Transvaal, viz., 15s. per 100 lbs. weight, which practically prohibits the introduction of coal into that country, where large quantities of local and inferior coal are used at the gold and silver mines, and for gas-making at Johannesburg. But with the extension of the Natal railways, which is now being negotiated, and the formation of a Customs Union of all the South African States, there can be no doubt that this present onerous duty will be abolished; such an abolition would enormously increase the output of coal, and give a great impetus to trade generally.

The Natal Government Railways are using local coal, thereby effecting a very considerable saving in working expenses.

The following are the quantities supplied by various collieries to the railway for 18 months ending November 26th, 1889:—

	Tons.
Elands Laagte colliery	9,561
Still's "	688
Ramsay's "	5,320
Wallsend "	974
Dundee "	37,112
Acol "	12
Lennoxton "	2,349
Total	56,016

The coal is used for domestic and for manufacturing purposes. It is also supplied to many steamers in the bay at Durban at about 20s. per

ton. During the year ending June 30th, 1890, 548 tons were exported; 1891, 19,928 tons; and in 1892, 30,000 tons were absorbed for bunkering and export purposes. In 1890, 81,000 tons of coal were raised, or more than double the output of 1889; in 1891, 93,551 tons; and in 1892, 118,932 tons.

There appears to be no reason why the bunkering trade alone should not exceed 80,000 tons per annum. For an export trade, however, Natal will have to compete with English coal at the Cape ports and with Australian coal at the Mauritius. The possibilities of the case, however, are undoubtedly in favour of Natal coal being sold at these ports. The Pungwe river (recently established) and Delagoa Bay are possible markets, but the demand at the latter place, however, amounts only to 4,000 tons.

The price at the pit's mouth has greatly fallen during the last two years, and is now under 10s. per ton. A director of one of the principal coal companies has stated that the cost of raising coal during one month (September, 1890) was 6s. 8d. per ton of round coal, which has been reduced since then.

The Natal Government Railway conveys coal at a fixed rate of ½d. per ton per mile, with a minimum rate of 2s. per ton. All coke and briquette fuel entering the colony is chargeable with duty at the rate of 3s. per ton. Mining and other machinery is admitted free of duty and conveyed at the lowest goods rate, viz., £3 5s. and £5 per ton respectively.

Climate.

The climate of Natal varies considerably, and although it is nearer the tropics than Cape Colony, its mean annual temperature is scarcely higher.

At Durban the highest temperature in the shade in September, 1890, was 110 degs. Fahr., which was very exceptional; the lowest being 47 degs. in July. In Newcastle the highest temperature in the shade last summer (at Christmas) was 96 degs., and the lowest showed about 10 degs. of frost in July. The winter is bright and dry, and cold at night in the uplands; while the summer heat is tempered by a cloudy sky, and almost daily thunderstorms and heavy rains.

Population.

By the census of 1891 the population was returned as:—Europeans, mainly British, 46,788; Indians, 41,142; natives, 455,983.

Labour.

Both coolie and native labour is used in mining operations, opinions differing as to which is the best. The native labour is very unreliable, as

the "boys" will not remain at their work more than a few months at a time, though, if well treated, they return again and again. Coolies, on the other hand, can be indentured for a fixed period, but such as have as yet been introduced into the colony have not proved so successful in the mines as on the railroads or sugar-cane fields.

The writer is of opinion that the right caste has not hitherto been introduced for mining work. Particulars as to wages, etc., have already been given under the heading of the Ramsay mine and Dundee colliery. White labour is scarce and very dear.

The price of mealies (Indian corn), the chief article of food with the natives, varies very greatly. The cost of feeding natives usually averages about 10s. per head per month, but in 1889, on account of the famine price of mealies, it cost, in Durban, about £1 10s. a head per month.

TIMBER.

Natal cannot be considered a well-wooded country, for with the exception of the coast-lands and in the kloofs of the Drakensberg range, the country is very bare in this respect. Arboriculture, however, has of late years been taken up to some extent, and certain kinds of trees are found to grow very well.

The trees most planted are pines *(Pinus insignis)* being most suited for mine timber, as well as being ornamental; black wattle *(Acacia decurrens*, variety *mollissima)* on account of its bark, used for tanning purposes, and gum trees, especially the blue gum *(Eucalyptus globulus)*. The rate of growth of these latter trees is most remarkable (see Appendix E).

Owing to the strong character of the roof, in no mine that the writer visited did he see many props. In fact, in the Dundee and Newcastle mines hardly a prop was used.

APPENDIX A.

In pursuance of the request of the Commissioner of Mines, the writer visited an alleged discovery of oil-shale and coal, cropping out on the side of one of the hills forming the Marotshiya ridge (Figs. 9 and 10, Plate XXIV.) between the Umkomanzi and Lotini rivers, in the county of Pietermaritzsburg, in January, 1892. This turned out to be a black-and-grey carbonaceous shale-bed, about 19 feet thick, but hardly an oil-shale; layers of bright shining coal, about half an inch thick, were interstratified with the shale.

Geologically, the discovery of this carbonaceous stratum was of great interest, as proof that in all probability coal of a workable thickness existed in the district. Owing to the extreme variableness of the coal-measures of the colony it is quite possible that this carbonaceous bed may at some other point contain considerably

more coal than at Antel's discovery, and in a more regularly stratified condition. The writer regrets that he was unable to devote time enough to visit Mileman's discovery, where he was informed the coal was much more developed than at Antel's.

It may be worthy of remark to state that the base of the coal-measures in the Impendhla district is at least 1,000 feet above the base in the Newcastle district. Commencing at Pietermaritzburg (where the altitude is 2,218·4 feet) we are on the Pietermaritzburg Shales; near the summit of Edendale Hill the upper beds of the series are found, characterized by the bright red and variegated colour of the shales and by beds of light-coloured concretionary sandstone, which latter presents very curious weathering effects.

The office of the administrator of native law in the Impendhla location is situate at about the base of the coal-measures, the altitude being (by aneroid) 5,190 feet or 2,810 feet above Pietermaritzburg. The coal-measures, which were discovered for the first time during the journey at the Impendhla, are easily located by their horizontal position and difference in colour from the lower rocks. Although the Pietermaritzburg Shale series was here and there traversed by dioritic dykes, it was very noticeable that on approaching the coal-measures and nearing the Drakensberg range, these became more numerous and so plainly visible that the writer was able to trace some of them for several miles.

The writer made a rough section of the Impendhla hill, which is shown in Fig. 11, along the line C D, in Fig. 9, Plate XXIV.

APPENDIX B.

Sections of Boreholes, etc., made by the Southern Cross Coal Mining Syndicate (Fig. 4, Plate XXIV.).

a.—Borehole.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Clay	3	0	3	0
Sandstone	29	8	32	8
COAL	0	2	32	10
Sandstone	9	0	41	10
COAL	0	0½	41	10½
Sandstone	8	2	50	0½
COAL	0	3	50	3½
Sandstone	4	0	54	3½

b.—Borehole.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Clay	3	0	3	0
Ironstone	1	0	4	0
Sandstone	14	8	18	8
Sandstone	10	3	28	11
Shale...	8	9	37	8
Sandstone	10	0	47	8
Shale...	9	5	57	1
Sandstone	20	3	77	4
COAL	0	8	78	0
Sandstone	9	2	87	2
COAL	0	9	87	11
Ironstone	9	5	97	4

c.—Borehole.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Clay	2	8	2	8
Ironstone	1	7	4	3
Sandstone	5	9	10	0
Sandstone	17	10	27	10

c.—Borehole.—*Continued.*

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Shale	0	7	28	5
Sandstone	10	0	38	5
COAL	6	0	44	5
Sandstone	25	5	69	10
COAL	2	1	71	11
Shale...	0	4	72	3
Sandstone	16	0	88	3

d.—Borehole.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Clay	15	0	15	0
Sandstone	10	4	25	4
Shale...	8	3	33	7
Sandstone	0	4	33	11
COAL	7	9	41	8
Sandstone	22	10	64	6
Shale...	2	8	67	2
Sandstone	0	6	67	8
Shale...	0	5	68	1
Sandstone	7	4	75	5
COAL	2	5	77	10
Shale...	0	2	78	0
COAL	0	5	78	5
Sandstone	1	2	79	7
COAL	2	1	81	8
Shale...	2	11	84	7
Sandstone	33	0	117	7
COAL	0	10	118	5

d.—BOREHOLE.—*Continued.*

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Shale	3	0	121	5
COAL	0	2	121	7
Sandstone	9	10	131	5
e.—SHAFT.				
Timbered	19	0	19	0
Sandstone	19	6	38	6
Shale	10	9	49	3
COAL	2	0	51	3
Shale parting ...	0	3	51	6
COAL	2	9	54	3

f.—BOREHOLE.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Clay	2	0	2	0
Ironstone	10	2	12	2
Sandstone	34	6	46	8
COAL	5	7	52	3
Sandstone	33	5	85	8
COAL	1	7	87	3
Shale	12	9	100	0
Sandstone	100	0	200	0

APPENDIX C.

SECTIONS OF BOREHOLES MADE ON THE BALLENGEICH FARM (Fig. 7, Plate XXIV.).

No. 1.—BOREHOLE.

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Sandy clay	24	5	24	5
Ironstone grit ...	0	2	24	7
Sandstone	2	5	27	0
Black band	0	7	27	7
Sandstone	12	5	40	0
No. 2.—BOREHOLE.				
Soil	9	0	9	0
Sandstone	55	1	64	1
Shale	6	1½	70	2½
Sandstone	3	0	73	2½
COAL	9	7	82	9½
Black splint band ...	0	4	83	1½
COAL	2	7½	85	9
Sandstone	18	0	103	9
No. 3.—BOREHOLE.				
Clay	13	0	13	0
Sandstone	42	7½	55	7½
COAL	0	5	56	0½

No. 3 BOREHOLE.—*Continued.*

Description of Strata.	Thickness of Strata. Ft.	In.	Depth from Surface. Ft.	In.
Sandstone	0	8¼	56	8¾
COAL	0	3	56	11¾
Sandstone	37	8	94	7¾
Shale	3	9	98	4¾
Sandstone	5	5	103	9¾
Shale	14	6	118	3¾
COAL	3	7	121	10¾
Black band	0	1	121	11¾
COAL	0	7	122	6¾
Black band	0	8	123	2¾
COAL	5	4	128	6¾
Black band	0	2	128	8¾
COAL	2	11¼	131	8
Sandstone	0	4	132	0
No. 4.—BOREHOLE.				
Soil	20	0	20	0
Sandstone	9	10½	29	10½
Whin	0	3	30	1½

APPENDIX D.

JOURNAL OF BORINGS ON THE BALLENGEICH FARM.

No. 1 BOREHOLE.

Date. 1891.	Bored in each Bed. Ft.	In.	Thickness of Bed. Ft.	In.	Total Depth. Ft.	In.	Core obtained. Ft.	In.	Nature of Strata.	Remarks.
Nov. 16	16	6	...		16	6	Nil.		Sandy clay ...	Waiting for pump casting.
„ 18	7	11	24	5	24	5	„		Do. ...	Received new pump and fitted up same.
	0	2	0	2	24	7	„		Ironstone grit.	
	2	5	2	5	27	0	„		Sandstone.	
	0	7	0	7	27	7	„		Black shale.	
	7	6	7	6	35	1	1	3	Sandstone.	
„ 19	4	11	...		40	0	0	6	Coarse sandstone grit, with black parting.	Finished boring, dismantled drill.

No. 2 Borehole.

Date. 1891.	Bored in each Bed.	Thickness of Bed.	Total Depth.	Core obtained.	Nature of Strata.	Remarks.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.		
Nov. 20	...	...	...	...	... ...	Shifting plant and erecting same at No. 2 site.
„ 21	0 10	0 10	0 10	Nil.	Black surface soil.	
	2 8	2 8	3 6	„	Yellow sandy soil.	
	1 6	1 6	5 0	„	Red ferruginous soil.	
	4 0	4 0	9 0	„	Stiff yellow clay.	
„ 23	4 0	4 0	13 0	„	Sandstone	Removing tents to No. 2 site.
	0 4	0 4	13 4	„	Dark sandstone.	
„ 24	1 6	1 6	14 10	...	Coarse white sandstone.	
	0 1	0 11	14 11	...	Very hard, fine, dark-brown sandstone.	
	11 7	11 7	26 6	...	Coarse white sandstone.	
	6 0	...	32 6	4 0	Hard grit sandstone.	
„ 25	15 1	...	47 7	11 6	Do. do.	
„ 26	16 6	37 7	64 1	4 3	Do. do.	
	2 6	...	66 7	1 4	Black, micaceous, and arenaceous shales.	
„ 27	3 7½	6 1½	70 2½	4 4	Do. do. ...	Core, part of yesterday's boring as well as to-day's.
	3 0	3 0	73 2½	...	White sandstone, hard.	
	8 1½	...	81 4	...	Coal, cubical near top, and bright.	
„ 28	1 5½	9 7	82 9½	...	Do. do.	
	0 4	0 4	83 1½	...	Black splint band.	
	2 7½	2 7½	85 9	1 0	Coal, anthracitic and slaty looking.	
	0 7½	...	86 4½	0 6½	Hard grey sandstone with pyrites.	
„ 30	...	...	...	...	... ...	Kaffirs carrying fire-wood during morning, and stopped by heavy rains rest of day.
Dec. 1	10 2½	...	96 7	3 1	Same as last, but free from pyrites	Lost 5 barrels of water in borehole, and stopped by heavy rain towards close of the day.
„ 2	7 2	...	103 9	10 0	Same as last	Core of yesterday's boring as well as to day's. Lost 5 barrels of water down borehole.

No. 3 Borehole.

Date. 1891.	Bored in each Bed.	Thickness of Bed.	Total Depth.	Core obtained.	Nature of Strata.	Remarks.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.		
Dec. 3, 4, & 5	...	...	...	...	... ...	Dismantling, shifting, and erecting drill and tents at No. 3 site.
„ 7 ...	13 0	13 0	13 0	Nil.	Stiff clay.	
„ 8 ...	16 4	16 4	29 4	2 4	Very close-grained sandstone, with bands of arenaceous, carbonaceous, and micaceous shale.	
	6 0	...	35 4	1 8	Coarse-grained sandstone, very hard.	
„ 9 ...	2 0	8 0	37 4	4 8	Do. do.	
	11 2½	11 2½	48 6½	6 4	Very close-grained sandstone.	
	1 0	1 0	49 6½	1 0	Sandstone, with thin bands of micaceous shale intermixed.	
„ 10 ...	2 3	2 3	51 9½	2 3	Sandstone, grey and hard.	
	3 10	3 10	55 7½	3 10	Very close-grained sandstone, with innumerable wavy bands of black micaceous shale, false-bedded.	
	0 5	0 5	56 0½	0 3	Coal, hard and bright, with thin dull bands.	
	0 8¼	0 8¼	56 8¾	0 8¼	Sandstone, with layers of arenaceous shale.	
	0 3	0 3	56 11¾	0 1	Coal, bright and anthracitic.	
	4 2	4 2	61 1¾	2 9½	Sandstone, with micaceous shale.	
„ 11 ...	5 2	...	66 3¾	2 6	Coarse white sandstone	Lost 36 barrels of water in borehole; shows breaks in sandstone.
„ 12 ...	2 0	...	68 3¾	2 0	Do. do. very hard	Do. 14 do. do.
„ 14 ...	6 7	...	74 10¾	0 8	Do. do.	Lost core in borehole and 20 barrels of water.
„ 15 ...	6 7¼	...	81 6	4 2 5 2	Do. do.	Found lost core; stopped half-day by heavy rain.
„ 16 ...	5 8¾	...	87 2¾	4 0	Do. do.	Stopped half-day; Kafirs carrying mealie-meal.
„ 17 ...	6 5	...	93 7¾	3 0	Do. do.	

No. 3 BOREHOLE.—*Continued.*

Date. 1891.	Bored in each Bed.	Thickness of Bed.	Total Depth.	Core obtained.	Nature of Strata.	Remarks.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.		
Dec. 18 ...	1 0	33 6	94 7¾	0 8	Coarse white sandstone.	
	3 9	3 9	98 4¾	2 0	Black arenaceous shale.	
„ 19 ...	1 5	1 5	99 9¾	1 5	Coarse white sandstone, very hard	Stopped for an hour by rain.
„ 21 ...	2 11	...	102 8¾	1 1	Fine-grained sandstone	Lost part of core in borehole; stopped one hour repairing pump.
„ 22 ...	1 1	4 0	106 9¾	1 3	Do. do.	Recovered lost core of yesterday.
				1 1		
	9 1	...	112 10¾	9 0	Sandstone alternating with bands of black micaceous shale, false-bedded.	
„ 23 ...	5 5	14 6	118 3¾	4 3	Do. do. do.	
	3 7	3 7	121 10¾	2 0	Coal.	
	0 1	0 1	121 11¾	0 1	Black band.	
	0 7	0 7	122 6¾	0 5	Coal.	
	0 4	...	122 10¾	0 3	Black shale.	
„ 24 ...	0 4	0 8	123 2¾	0 3	Do.	
	5 4	5 4	128 6¾	1 0	Coal, bright, glossy, cubical towards bottom.	
	0 2	0 2	128 8¾	0 1	Black band.	
	2 11¼	2 11¼	131 8	2 4	Coal, dark anthracitic, with layers of pyrites.	
	0 4	...	132 0	0 4	Very hard close-grained greyish sandstone.	
No. 4 BOREHOLE.						
Dec. 29	20 0	20 0	20 0	Nil.	Surface soil.	
„ 30	7 0	7 0	27 0	...	Soft sandstone.	
	2 10½	2 10½	29 10½	...	Coarse, gritty sandstone.	
	0 3	...	30 1½	0 3	Whinstone	It took 5 hours to bore into 3 inches of this igneous mass.

APPENDIX E.

In Mr. H. G. Fourcade's "Report on the Natal Forests" to the Colonial Government, 1889, we find the following particulars as to the growth of gums in the vicinity of Pietermaritzburg:—"Production of wood. In the case of gums the rate of growth may be ascertained accurately, as there are sufficiently old plantations of the kind in Natal. Mr. Topham's plantation near Pietermaritzburg may be taken to be a fairly average one. The oldest plot—40 acres in area—is seventeen years old, and consists of mixed *Eucalyptus globulus*, *Eu. longifolia*, and *Eu. rostrata*, the rate of growth of each appearing not to differ widely. The trees are planted 12 feet apart, so that there are 302 to the acre; they average 4 feet 10 inches in girth at 3 feet from the ground, and 115 feet in height . . . the contents of each tree average 96·3 cubic feet and standing stock per acre 29,083 cubic feet, representing a yearly increment of 1,711 cubic feet per acre. The weight of a cubic foot of *Eu. globulus* (dry wood with bark) averages 40lbs." To Mr. Topham, who has made a study of the subject for many years, the writer is indebted for much general information relating to arboriculture in the colony.

Individual trees of *Pinus insignis*, growing near Howick, show an average yearly increase of 6 inches in girth, attaining a height of 45 feet in ten or twelve years.

APPENDIX F.

When boring on the Walmsley farm (Fig. 3, Plate XXIV.), all the holes were drilled by contract, a hand-worked diamond drilling machine being employed in this as in all other borings. The price paid was 10s. per foot for the first 100 feet, and 15s. per foot for the second 100 feet; all loss of diamonds, break down of machinery, etc., being borne by the contractor.

Mr. Clayton, the contractor, informed the writer that he had obtained the following results in the Newcastle district:—

Holes drilled, 11.
Extreme distance apart, 5 miles.
Total length drilled, 1,144 feet.
Total working days, 50.
Total working hours per day, 10·5.
Average depth drilled per day, 22·88 feet.

The only labour used was Zulu or Swazi-Kafir.

When boring on Ballengeich farm, the writer had the use of the Government drills on paying labour and upkeep. The cost per foot was 3s. 6d., but in this case he personally superintended everything. All the holes were 1½ inches in diameter.

APPENDIX G.

Report upon Natal Coals, by E. Nevill, F.I.C., F.C.S., etc., etc., Government Chemist and Official Assayer for Natal.

I.—Scheme of Analysis.

The technical examination of a coal may be divided into five sections, as follows:—(*a*) The general analysis; (*b*) the quantitative determination of the principal constituents; (*c*) the examination of the physical character; (*d*) the determination of the efficiency as fuel; (*e*) the examination of special properties.

(*a*) The first of these five divisions comprises the determination of the amount of:—i., moisture; ii., volatile hydrocarbons; iii., fixed hydrocarbons; iv., sulphur (total); v., ash.

The determination of these five quantities forms the general analysis of the coal, and serves to indicate its character and probable value as a fuel or for manufacturing or for metallurgical purposes.

The moisture usually ranges between 1 and 3 per cent.

The volatile hydrocarbons vary in quantity from under 15 per cent. in anthracite coals to over 40 per cent. in bituminous coals, and form the portion of the coal giving rise to the flame and smoke.

The fixed hydrocarbons, or the coke free from ash, constitutes the portion of the coal from which is derived the greater part of its heating power. In anthracite coals the fixed hydrocarbons usually amount to over 80 per cent. of the coal, whilst in the bituminous coals the amount falls to less than 50 per cent.

The total amount of sulphur present in a coal is one of the most important factors in determining the value of a coal. In the better class of English coals it varies between ⅜ per cent. and 1½ per cent.

The ash, or mineral constituents, of the coal should not exceed 10 per cent., the better class of English coals having rather less than half this amount.

The sum of these five quantities will be found to exceed 100, this apparent anomaly being due to the fact that the ash found on burning the coal is really larger than the real inorganic constituents of the coal, and includes a portion of the sulphur and carbon independently reckoned under other heads.

(*b*) The second division affords the data for determining the constitution of the coal, and thus ascertaining its true value. It may be subdivided into:—

Organic constituents—vi., carbon; vii., hydrogen; viii., nitrogen and oxygen; ix., sulphur.

The actual efficiency of a coal depends on the amount of carbon and hydrogen that it contains, as it is the combustion of these constituents which generates the heat evolved on burning. They form over 85 per cent. of the best class of coals. The amount of nitrogen and oxygen are of lesser importance, it mainly serving to indicate the character of the coal. The proportion of sulphur which exists in the coal in combination with the organic constituents is important, because this portion of the total amount of sulphur exerts far less injurious effect than that which is present as pyrites.

The sum of these four percentages constitutes the organic or true coal, and the ratio of the fixed to the volatile hydrocarbons serves to indicate the real nature of the coal. In anthracite coals the ratio usually exceeds 4 to 1, whilst in the bituminous coals it is generally less than 2 to 1.

The second sub-division is:—

Inorganic constituents—x., sulphur as pyrites; xi., sulphur as sulphates; xii., iron as pyrites; xiii., iron as ash; xiv., pyrites (total).

These inorganic constituents are of less importance, the only one possessing special value being the amount of sulphur existing as pyrites, as it is under this form it exerts most injurious effects. The sulphur as sulphates is quite uninjurious. The total amount of pyrites is always slightly greater than the sum of the sulphur and iron existing as pyrites, as the pyrites always contain a small quantity of other constituents.

(*c*) The principal physical data required for the determination of the character and value of a coal consist of:—(a) specific gravity; and (b) hardness; (c) friability; (d) relative cleanliness: (e) co-efficient of deterioration.

The four last of these are measured on an arbitrary centesimal scale, the quality being denoted by some decimal number between 0·00 and 1·00.

The specific gravity gives the weight of a given volume of coal when the weight of an equal volume of water is taken for unity. The greater the specific gravity the larger the weight of coal which can be stored or carried in the same space.

The hardness of a coal is measured on a scale which makes 0·10 represent a soft imperfect coal, and 0·90 denote a hard stone-like coal.

The friability or propensity to break up into small pieces is measured on a scale which makes 0·10 represent a strong stone-like coal, and 0·90 denote a soft crumbling coal, easily broken up in the fingers.

The relative cleanliness is measured on a scale which makes 0·10 represent a coal full of cavities filled with sandy clay and carrying scattered masses of shale, clay, etc., whilst 0·90 denotes a homogeneous clean coal, free from all signs of foreign matter. No coal can be called clean which does not come up to 0·80 on this scale.

The co-efficient of deterioration measures the stability of a coal or its power of resisting the injurious effects of exposure to air, moisture, and variations of climate. On this scale 0·10 represents a coal little altered by long exposure, whilst 0·90 denotes a coal which is quickly spoilt.

(*d*) Under the head of efficiency, there have been placed the results obtained for judging of the value of the coal by practical trial with an experimental boiler and furnace. These results may be divided under the heads:—(1) evaporative power; (2) residue; (3) smoke; (4) character of fire.

Under the head of evaporative power is given the pounds of water converted into steam by one pound of coal, and the number of pounds of coal that can be economically burnt per square foot of fire-grate area. Upon the scale adopted, the evaporative power of the principal coals may be taken as approximately:—

	Lbs.
Anthracite (best) coals	10·5
Best Welsh steam navigation coals ...	10·0
Welsh steam coals	9·5
North country	8·8
Yorkshire hard steam coals	8·3
Scotch steam coals	8·0
Lancashire coals	7·8

With regard to the speed with which a coal should be capable of being burnt with economy and completeness, it should not be less than 18 lbs. of coal per hour per square foot of fire-grate area, and it is desirable that it should be over 20.

The amount of residue left by a coal on burning should not exceed 15 per cent., and it consists usually of about equal parts of clinker and ashes.

The smoke is given on the Admiralty scale, according to which:—

0 = No smoke.
1 = Smoke just visible.
2 = Light brown smoke fully visible.
3 = Brown smoke, sky visible through smoke.
4 = Dark brown smoke, nearly opaque.
5 = Dark brown smoke, opaque.
6 = Black smoke.
7 = Dense black smoke.

The heading, character of fire, needs no explanation.

(*e*) The only point considered under this heading is the coke left by the coal, but so much depends upon the method by which the coke is made, and the examination has been restricted to determining whether or not the coal is capable of giving a true coke.

II.—Description of Walmsley Coal.

A single sample (of about 2 cwts.) from this property.

It was taken from the upper portion of the seam above the separating band of black shale, from near the outcrop, where the coal has become much weathered.

It is a hard compact greyish coal with a silky lustre, breaking with a semi-conchoidal fracture into rhomboidal masses, and containing small cavities filled with sandy clay. The surface of the coal and the cleavage planes were stained yellow from the oxidation of the thin films of grey iron pyrites carried by the coal.

	Per Cent.
(*a*) *General Analysis.*	
Moisture	2·73
Volatile hydrocarbons	29·54
Coke	53·40
Sulphur	1·17
Ash	14·00
Sum	100·84
(*b*) *Constitution.*	
Organic Constituents—	
Carbon	70·91
Hydrogen	4·73
Nitrogen and oxygen	6·35
Sulphur	0·62
Sum (true organic coal)... ...	82·61
Volatile hydrocarbons	35·50
Fixed hydrocarbons	64·50
Ratio...	1·81
Inorganic Constituents—	
Sulphur as pyrites	0·49
Do. as sulphates	0·06
Iron as pyrites	0·43
Do. as ash	0·23
Pyrites (total)	0·92
Easily oxidised sulphur	0·08
(*c*) *Physical data.*	
Specific gravity	1·463
Hardness	0·45
Friability	0·40
Relative cleanliness	0·75
Coefficient of deterioration	0·20
(*d*) *Efficiency.*	
Evaporative power—	
Pounds of water evaporated per pound of coal	9·00
Pounds of coal burnt per hour per square foot of grate area	18·00
Residue (in percentages)—	
Clinker	8·45
Ash	9·22

Federated Institution of Mining Engineers.
Transactions 1892-93.

To illustrate M

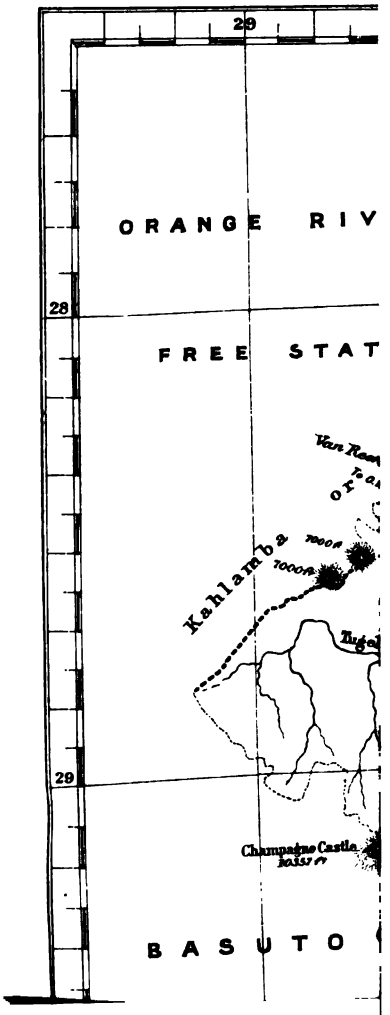


FIG. 9.

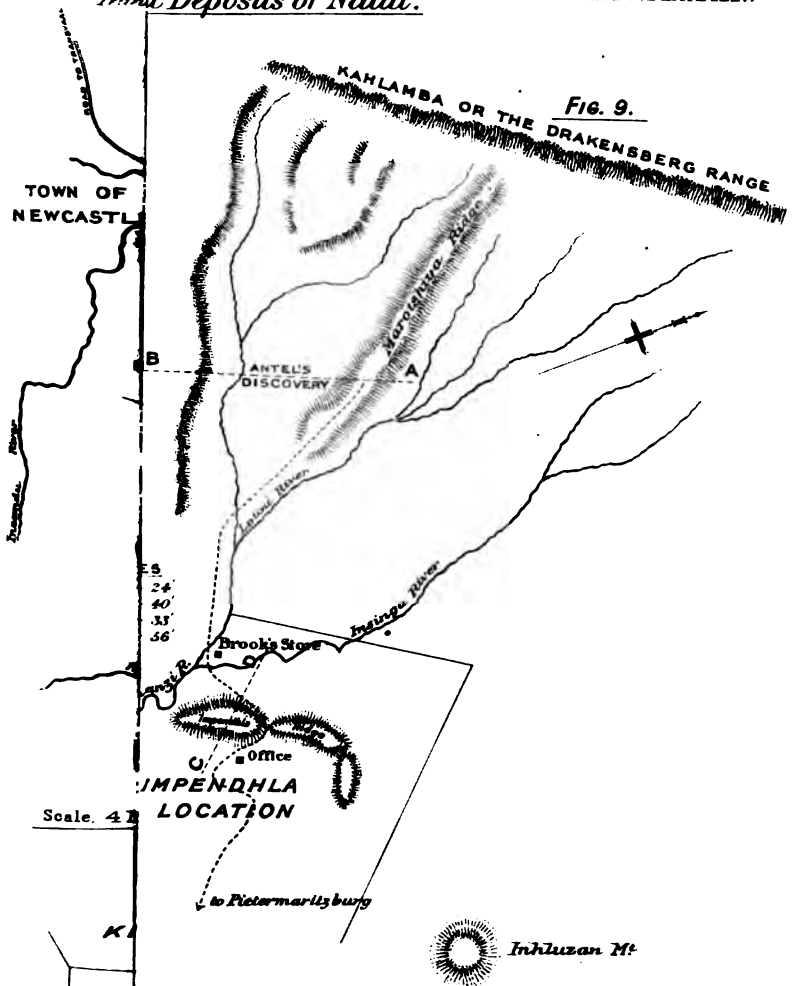
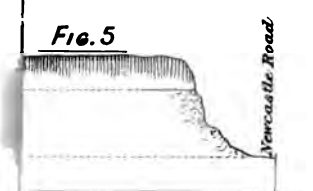


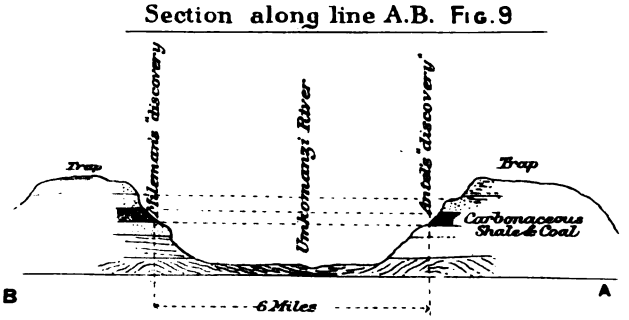
FIG. 5



0 Chains to 1 Inch
0 Feet to 1 Inch

FIG. 10

Section along line A.B. FIG. 9



Smoke (in Admiralty scale numbers)—	Per Cent.
Maximum	1·40
Mean	0·60
Percentage of time when no smoke ...	80·00

Character of Fire.—Coal lights fairly well, and burns with a little flame to a dull red mass. Burns better under a forced draught, yields a good deal of soft shaly clinker, which does not adhere to the bars, and a quantity of soft grey ash.

(*e*) *Coke.*—Yields a cindery black coke, soft and friable, and of very indifferent quality.

The CHAIRMAN said he was glad to be able from a personal acquaintance with the coal-field described to speak of the value of this paper, because at the present time the key to the supply of coal to vessels in that part of the world was no doubt the coal-field found in Natal. The coal-seams were most puzzling, and gave rise to two conflicting and opposite opinions—one suggesting that the seams were as continuous as those of European and American coal-fields; and another of contrary opinion, and he (the Chairman) from his own observation agreed with the latter. It was absolutely necessary to prove the entire area of a coal-field before they could say it was continuous. Another difficulty in this colony was the manner in which they had laid out their railways. Severe gradients and curves had prevented its natural development, and they must now face the cost of duplicating the single line. Probably the cheapest and best way would be to form another railway to the coast. There was further difficulty at the port, ships having to lie off a considerable distance from the coast, everything being loaded over the side. He noticed in the paper that "the authorities have, however, under consideration the erection of hydraulic tipping-appliances designed by Sir W. G. Armstrong, Mitchell, & Co., to suit the 20 tons trucks of the Natal Government Railway, which will greatly reduce the cost of coaling." In his opinion the 20 tons trucks and the shipping arrangements would require reconsideration. The coal industry of Natal might not affect this country materially as a competitor, but it was valuable as a means of coaling English ships in the Indian Ocean, and he considered the extent of the available coal would warrant the energetic development which the colonials were making.

Mr. T. E. FORSTER said that although he was not acquainted with this particular coal-field, there were several points which appeared to agree with mining experiences in other colonies; for instance, the leaving of small pillars. Had there been any difficulties in consequence of this? In Australia, where the coal-seams appeared to be somewhat the

same, so far as general conditions were concerned, there was difficulty in getting pillars, left many years ago, without, in many cases, bringing on a serious crush. The railway mileage rates compared favourably with other countries of the same kind. With regard to the export trade they might often be able to supply the coal at a cheaper rate to certain stations, where there was a demand for it, but it was often found that such trade did not depend so much on price as on the possibility of obtaining tonnage to carry it. Vessels would always go where best paying freights took them, and consequently it might be difficult to carry on an export trade with sufficient steadiness to suit regular customers.

Mr. W. COCHRANE asked Mr. Redmayne to give the quoted prices of Australian and English coals in the competing markets mentioned in his paper?

Mr. JOHN BIGLAND said the writer described the deposits as aqueous. Did he mean marine or freshwater deposits? They had very few papers with regard to coal-fields in the Triassic system, and it was somewhat new to many of them. He was prepared to believe, after hearing the paper, that it was a marine deposit, and that the coal had been deposited as drift in the same way as Continental geologists asserted.

Mr. M. WALTON BROWN asked whether the analyses given were the results of average samples of the seam, or from picked portions of the coal separated from stone?

Mr. REDMAYNE said they were from an average sample, but without band.

Mr. COCHRANE—A sample of the marketable coal?

Mr. REDMAYNE—Yes.

Mr. REDMAYNE, replying to the discussion, said there was some talk of doubling the railway, but it was regarded as impossible, the bridges being only made for a narrow-gauge (3½ feet) railway, and it would be found cheaper to make an independent railway to Durban. Subsidences had taken place owing to attempts made to remove the thin pillars; he had been asked and had recommended certain precautions being taken during the removal of such pillars, but his views were not accepted at the time.

On the motion of the CHAIRMAN a vote of thanks was accorded to Mr. Redmayne, and discussion of the paper was adjourned.

APPENDICES.

I.—REPORT OF THE CORRESPONDING SOCIETIES COMMITTEE OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1892.*

The Corresponding Societies Committee of the British Association begs leave to submit to the General Committee the following Report of the proceedings of the Conference held at Cardiff.

The meetings of the Conference were held on Thursday, August 20th, at 3·30 p.m., and on Tuesday, August 25th, at 1 p.m., in the Dumfries Street Proprietary School.

* * * * * * * * * * * * * * *

At the first Conference (August 20th) the chair was taken by Mr. G. J. Symons, F.R.S., the Corresponding Societies Committee being also represented by Sir Douglas Galton, Dr. Garson, Mr. W. Whitaker, Mr. W. Topley, and Professor R. Meldola as Secretary.

* * * * * * * * * * * * * * *

SECTION A.

Temperature Variation in Lakes, Rivers, and Estuaries.— * * * *

Meteorological Photography.— * * * * * * * * *

SECTION C.

Geological Photography.—The Rev. J. O. Bevan announced that on his representation the Woolhope Club had recently appointed a Committee to deal with this subject, and he hoped that their efforts during the year would be of use to the Geological Photographs Committee.

Mr. O. W. Jeffs stated that the work of this Committee, of which he was Secretary, had made satisfactory progress during the year, and he expressed his thanks to the Corresponding Societies not only for the assistance which they had rendered by supplying photographs, but also for the interest which they had raised in different parts of the country. As a result of the work an exhibition of photographs had been arranged in the meeting room of Section C. The total number of photographs received during the year was 300. With respect to amateur photographic societies Mr. Jeffs stated that their Committee had not yet received from them the assistance which they had hoped. Although a large number of people in England, Scotland, Ireland, and Wales had helped them, it was necessary to point out that what was now wanted was work of a more systematic character. The Yorkshire Naturalists' Union had sent in the largest number of photographs received from any one society. The East Kent Natural History Society had also formed a photographic section, and had sent in the results, but in other parts of the country work had not been carried on to the same extent, and he hoped that some of the delegates would advocate their cause and promote local photographic surveys on a systematic plan.

* Reprinted by permission of the Council of the British Association.

Mr. Wm. Gray remarked that the Committee must not be discouraged by the limited number of photographs which might be sent in during any particular year, because at the present stage, when the whole scheme was being organised, the number of photographs did not indicate the amount of work that was being done. Thus the Belfast Naturalists' Field Club had been well represented last year, but would not be so well represented this year, because they were engaged in organizing their work and preparing their own lists. When these were ready the work would progress more rapidly.

Mr. Cushing presented two photographs on behalf of the Croydon Microscopical and Natural History Club.

The Rev. H. H. Winwood raised a question with respect to the obtaining of copies of the photographs. The amateur photographer took the negatives, but did not wish to be troubled with multiplying prints. He thought it desirable that the name of the person holding the negative should be made known in order that copies of any particular photograph might be obtained.

Mr. Gray stated that this was one of the points which had been considered by their Society in Belfast, and they proposed to inform the public where copies of the photographs were to be obtained.

Mr. Sowerbutts said he knew a considerable number of amateur photographers who would not send away their negatives to be printed from, nor would they allow prints to be made without their consent. He had tried to do something for the Committee with amateur photographers in Lancashire, but had found that the amateur who went out to photograph did not usually confine himself to such subjects as were required by the Committee. About 120 negatives had been taken by the Manchester Geographical Society, but these had not been taken specially for Geological purposes, and only four had been sent to the Committee. The Manchester Geological Society, represented by Mr. Mark Stirrup, took photographs for scientific and not for mere pictorial purposes, and these would, no doubt, be of greater value. Their Geographical Society had, however, arranged to take a series across Lancashire for their own purposes, and any of the photographs showing geological features would, he thought, be at the service of the Committee.

Mr. Jeffs said that, in order to remove any misconception which might exist with respect to the purpose of the Committee, he would state that their first object was to have a typical collection of photographs illustrating the geological features of the country. Their next object was to enable teachers and lecturers to have copies of any of the photographs that might be desired. In furtherance of this object they had already published in their Report for 1890,* and had continued in their present Report, a list of photographs, giving particulars and the name of the photographer from whom they could be procured. Any person wanting copies could obtain them by writing. Of course the fixing of price was a local matter and beyond the control of the Committee; he thought that some of the photographers might be generous enough to present copies in the interests of science. Mr. Jeffs added that their Committee could not undertake to hold the negatives.

Mr. C. J. Watson suggested that copies of the photographs should be circulated among the Corresponding Societies, as they could not tell from the published list which of the photographs would be of use to a local Society. He thought that this would be met by having an album of duplicate prints for circulation in the manner suggested.

Mr. A. S. Reid said that he had been engaged for some time in inciting the local Societies to take up this work. He found that the amateur geologist was not

* *B. A. Report*, Leeds, 1890, page 429.

inclined to add to the weight which he had to carry. The appliances for taking good photographs need not, however, be very heavy, as he had been experimenting with an ordinary hand camera, weighing five pounds, which he had carried over some of the rockiest parts of Scotland. He had contributed a short paper to the *Photographic Quarterly* for January, 1891, showing what could be done with one of these small cameras. Mr. Reid exhibited a print taken from one of these quarter-plate negatives, which he considered quite good enough for preparing larger diagrams from for teaching and lecturing purposes.

Mr. Holgate expressed his regret that the Committee could not undertake the care of the negatives, as he was of opinion that many photographers would be willing to take two negatives of any section, one for the use of the Committee, for the purpose of supplying prints at some fixed charge to the societies or individuals requiring them.

The Chairman stated that the Meteorological Photographs Committee had never experienced any of the difficulties referred to with respect to the negatives; those who took the photographs were in all cases willing that free use should be made of them by the Committee, and he expressed the hope that in the interests of science it might be the same with kindred subjects.

Sea Coast Erosion.— * * * * * * * * * * *

SECTION D.

Disappearance of Native Plants.— * * * * * * * *

Destruction of Wild Birds' Eggs.— * * * * * * * *

SECTION E.

Teaching of Geography in Primary Schools.— * * * * * *

Ordnance Maps.—The Chairman stated that at the Leeds meeting last year a strong recommendation had been sent up to the Council as to the cost, the antiquity, and the difficulty of procuring copies of the Ordnance maps. The Council had communicated with Mr. Chaplin, of the Board of Agriculture, and they had heard unofficially that material alterations would be made, so that these maps would be very much more accessible than heretofore. He added that, so far as his experience went, nineteen-twentieth of the people of this country did not know how to make use of an Ordnance map.*

Mr. Holgate said that it would be desirable to have the contours of different heights printed in different colours. It would then be easy for teachers to get their pupils to trace out these contours and cut them out in cardboard. For teaching geography in an interesting way they could not, in his opinion, have anything better than a raised map, made in this manner.

Mr. Peter Price mentioned, as an illustration of the slow progress of the survey, that the town of Cardiff had purchased new maps, which had been found to show only about one-half the present town. The survey had been made ten years ago, and the maps were quite useless for the purpose for which they had been purchased.

Mr. Mills said that it was only fair to state that he had never written to Stanford's for any map without receiving it by return of post.

* The following resolutions were referred by the General Committee to the Council for consideration and action if desirable at the Cardiff meeting:—(1) "That the publication of the 1 inch and 6 inches Ordnance Survey Map is, in the interests of Science, urgently required at the earliest possible date, no less than in the interest of Industry, Manufacture, and Technical Education. (2) That steps be taken and provision made for keeping the Ordnance Maps up to date. (3) That the Maps should be made more accessible to the public, and should be sold at a lower price, as is the case in nearly all other official publications, such as Admiralty Charts, Blue Books," etc.

Mr. Gray was of opinion that the maps should be sent gratuitously to schools. The children often had no idea of what a map meant, and they should have the maps of their own districts on different scales, in order that they might gain a better knowledge of geography.

The Chairman stated that he had recently been to Clevedon, and had been unable to procure the Ordnance map from the best shop in the town. He had written to Stanford and obtained one in two days, and had found that the map was twelve years old.

Mr. Whitaker said that there was no difficulty in getting 1 inch maps with the contours printed on them as the Ordnance Survey was now engaged in producing such maps. The work required time, however, as the copper plate of a 1 inch map took a year to engrave. If the Government could be forced into using photo-zincography the maps might be produced more rapidly. He knew that nearly all the 1 inch maps were to be procured with contours, although not with hill shading. Processes were now being tried at Southampton for printing in the hill shading in a transparent ink which would not obscure the lettering, the roads, rivers, or contour lines, etc. The chief delay occurred in the engraving, but the maps were always dated. With respect to the 6 inches maps, Mr. Whitaker said that local surveyors or anyone who could pace accurately could fill in new features for themselves. In condemning a map as being of no use, all that was meant was that the new features had not been put on it, and that, of course, was bound to happen in growing towns like Cardiff, Manchester, and Southampton. The Government did not give the Survey the means of going over the ground again. The only way of hastening matters and of insuring the insertion of the latest features would be to influence the Treasury, which controls all the Government Departments.

Mr. Sowerbutts expressed his belief that the delay was mainly in the method of producing the maps. He had been surprised at the facility with which the Survey map were produced in Brussels for about 4d. each directly from the zinc plates.

Mr. Kenward expressed his admiration for the 1 inch Ordnance map. He said that he had made forty or fifty journeys on foot through every part of North Wales and had never found the map at fault.

SECTION G.

Flameless Explosives.—Professor Merivale stated that there was nothing new to report this year. The work was still going on, and next year they would have something definite to bring before the Delegates.

Mr. Mills said that the Chesterfield and Midland Counties Institution had been carrying on similar experiments, and it was to be regretted that both institutions were spending money and time over the same work.

The Chairman expressed the hope that they would combine to carry on the experiments together.

SECTION H.

Aid in Anthropological Exploration.— * * * * * * *

Registration of Prehistoric Remains.— * * * * * * *

At the second Conference (August 25th) the chair was taken by Mr. G. J. Symons, F.R.S., the Corresponding Societies Committee being further represented by Sir Douglas Galton, Mr. Whitaker, Dr. Garson, and Professor Meldola as Secretary.

SECTION A.

Temperature Variation in Lakes, Rivers, and Estuaries.— * * * *

Meteorological Photography.— * * * * * * * * *

SECTION B.

Inquiry into the Condition of the Atmosphere of Manufacturing Towns.— * *

SECTION C.

Geological Photography.—Mr. A. S. Reid said that their Committee had met since the last Conference, and had arrived at certain conclusions, which would be made known in due course. They had applied for a grant for the purpose of mounting the photographs, and a systematic method had been agreed upon, so that the prints could be mounted and handled without injury. The subject of lantern slides had been mentioned, but they had decided that the collecting of these did not come within their province.

Earth Tremors.—The Chairman stated that this Committee had, during the past year, been collecting apparatus and diagrams of apparatus for recording earth tremors. They had not yet come to any decision as to the best form of instrument, and they would be glad of any suggestions from those interested in the subject.* Application had been made for reappointment without a grant.

SECTION D.

Disappearance of Native Plants.— * * * * * * * *
Destruction of Wild Birds' Eggs.— * * * * * * * *
Popularising of Natural History Studies.— * * * * * * *
Botanical Demonstrations for Teachers.— * * * * * * *

SECTION H.

Description of Museum Specimens.— * * * * * * * *
Registration of Prehistoric Remains.—* * * * * * * *
Aid in Anthropological Exploration.—* * * * * * * *

Interchange of Publications.—Among subjects of general interest discussed at the Conference was the importance of the Corresponding Societies freely interchanging their Transactions, Proceedings, and other publications. It was pointed out that, while printing, the additional cost of an extra 50 or 100 copies would be very trifling. Many of the Corresponding Societies are already in the habit of sending their publications to kindred Societies. The Hampshire Field Club deposits all such publications in the Southampton Public Library, so as to render them freely accessible.

On the motion of Mr. Holgate, a vote of thanks was passed to the Chairman for presiding at the Conferences.

The Committee recommends the addition of the following Societies to the list:—

1. The Federated Institution of Mining Engineers.
2. The Liverpool Geographical Society.

On the other hand it has to announce the withdrawal of the Royal Scottish Geographical Society.

* The Secretary of the Committee is Mr. C. Davison, 38, Charlotte Road, Birmingham.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1892–93.

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Barnsley Naturalists' and Scientific Society, 1867	Barnsley Nat. Sci. Soc.	Henry Wade, 10, Pitt Street	60	None	6s. and 10s. 6d.	Transactions, occasionally.
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C. ..	W. W. Martin, Royal Literary and Scientific Institution, Bath	90	5s.	10s.	Proceedings, annually.
Bedfordshire Natural History Society and Field Club, 1875	Beds. N. H. Soc. F. C. ..	T. Gwyn Elger, F.R.A.S., Beaumont House, Shakespeare Road, Bedford	1,000	None	£1 5s. and 10s. 6d.	Transactions, occasionally.
Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	270	None	£1 1s.	Report and Proceedings, annually.
Belfast Naturalists' Field Club, 1863..	Belfast Nat. F. C. ..	Museum, College Square. R. Lloyd Praeger.	323	None	5s.	Report and Proceedings, annually.
Birmingham Natural History and Microscopical Society, 1858	Birm. N. H. M. Soc. ..	W. H. Wilkinson and William P. Marshall, Mason College, Birmingham	200	None	£1 1s.	"Midland Naturalist," monthly.
Birmingham Philosophical Society ..	Birm. Phil. Soc.	T. W. Bridge and J. Landon, Medical Institute, Edmund Street, Birmingham	105	None	£1 1s.	Proceedings, annually.
Bristol Naturalists' Society, 1862 ..	Bristol Nat. Soc. ..	University College, Bristol. Professor Adolph Leipner, 38, Hampton Park, Redland, Bristol	217	5s.	10s.	Proceedings, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc..	46, High Street. G. Harris Morris, Ph.D., F. I. C., 6, Alexandra Road, Burton-on-Trent	221	None	5s.	Annual Report. Transactions, occasionally.
Cardiff Naturalists' Society, 1867 ..	Cardiff Nat. Soc. ..	R. W. Atkinson, B.Sc., F.I.C., 44, Loudoun Square, Cardiff	400	None	10s. 6d.	Report and Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci. ..	Grosvenor Museum, Chester. G. R. Griffith	650	None	5s.	Annual Report. Proceedings, occasionally.
Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15, Cavendish Street, Chesterfield	267	£1 1s.	Members, 31s. 6d.; Subscribers, 21s.; Associates and Students, 20s.	Transactions of Federated Institution of Mining Engineers, about every two months.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	350	None	Minimum, 10s. 6d.	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc. ..	G. B. Millett, Penzance..	100	None	£1 1s.	Report and Transactions, annually.
Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C. ..	Public Hall, Croydon. Walter Budgen	290	None	10s.	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc. ..	J. B. Bailey, 28, Eaglesfield Street, Maryport	848	None	6s.	Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C. ..	N. M. Richardson, Montevideo, Chickerel, Weymouth	280	None	10s.	Proceedings, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Fern Bank, Maxwelltown, Dumfries	204	2s. 6d.	5s.	Transactions and Journal of Proceedings, annually.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1892-93.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
East Kent Natural History Society, 1857	E. Kent N. H. Soc. ..	39, St. George's Street, Canterbury. W. P. Mann, B.A., Langton School	73	None	Ladies, 5s.; Gentlemen, 10s.	"South Eastern Naturalist," occasionally.
East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 12, Townsend Crescent, Kirkcaldy, N.B.	9 Societies 1,008 Membs.	None	Assessment of 4d. per member	Proceedings, annually.
Edinburgh Geological Society, 1834..	Edinb. Geol. Soc. ..	H. M. Cadell, 5, St. Andrew Square, Edinburgh	226	10s. 6d.	12s. 6d.	Transactions, annually.
Essex Field Club, 1880	Essex F. C.	William Cole, 7, Knighton Villas, Buckhurst Hill, Essex	450	10s. 6d.	15s.	"Essex Naturalist," monthly.
Federated Institution of Mining Engineers	Fed. Inst. Min. Eng. ..	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,400	None	None	Transactions, about every two months.
Glasgow, Geological Society of, 1858	Glasgow Geol. Soc. ..	J. B. Murdoch, Capelrig, Mearns, Glasgow	240	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc. ..	D. A. Boyd and J. Steel, 207, Bath Street, Glasgow	325	7s. 6d.	7s. 6d.	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc. ..	John Mayer, 207, Bath Street, Glasgow	692	£1 1s.	£1 1s.	Proceedings, annually; occasional papers.
Hampshire Field Club, 1885	Hants. F. C.	Hartley Institution, Southampton. W. Dale	250	None	7s. 6d.	Proceedings, annually.
Hertfordshire Natural History Society and Field Club, 1875	Herts. N. H. Soc. ..	Dr. J. Morrison, F.G.S., St. Albans, and F. M. Campbell, F.L.S., Hoddesdon	255	10s.	10s.	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C. ..	A. J. Crosfield, Carr End, Reigate	75	10s.	10s.	Proceedings, usually every two years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc. ..	F. A. Black, 16, Union Street, Inverness	167	None	5s. and 2s.	Transactions, occasionally.
Ireland, Royal Geological Society of, 1831	R. Geol. Soc. Ireland ..	Prof. W. J. Sollas, F.R.S., Trinity College, Dublin	140	None	£1 1s.	Journal, generally annually.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland ..	W. F. Bailey, Prof. Bastable, and J. Pim, 35, Molesworth Street, Dublin	102	None	£1.	Journal, annually.
Leeds Geological Association, 1874 ..	Leeds Geol. Assoc. ..	Wm. Lower Carter, F.G.S., Meanwood, Leeds	141	None	5s.	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1878	Leeds Nat. C. Sci. Assoc.	80, Municipal Buildings, Victoria Square, Leeds. Arthur Walker	251	6s.	6s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, Town Museum, Leicester	303 Members, 32 Associates.	None	Members, £1 1s.; Associates, 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875..	Liv'pool E. Soc.	Royal Institution. R. F. C. Annett, Liverpool	213	None	Residents, £1 1s.; Non-residents, 10s. 6d.	Transactions, annually.
Liverpool Geographical Society, 1891	Liv'pool Geog. Soc. ..	G. A. Craig, F.R.G.S., 6A, The Temple, Dale Street, Liverpool	330	None	£1 1s.	Uncertain.
Liverpool Geological Society, 1858 ..	Liv'pool Geol. Soc. ..	Royal Institution. H. C. Beasley ..	54	None	£1 1s.	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc...	Royal Institution. John Rutherford, LL.B., Wason Chambers, 4, Harrington Street, Liverpool	271	10s. 6d.	£1 1s.	Proceedings, annually.

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Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Liverpool Microscopical Society, 1869	Liv'pool Mic. Soc. ..	Royal Institution. Wm. Oelrichs, Sunnyside, Oxton, Cheshire	122	10s. 6d.	10s. 6d.	Journal, generally annually.
Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc. ..	Thomas J. Blanche and W. Sutherland, Malton, Yorkshire	90	None.	5s.	Report, every two years.
Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Masonic Rooms, Ramsey, Isle of Man	134	2s. 6d.	Gentlemen, 6s.; Ladies, 3s.	Yn Lioar Manninagh, quarterly.
Manchester Geographical Society, 1885	Manch. Geog. Soc. ..	Eli Sowerbutts, F.R.G.S., 44, Brown Street, Manchester	850	None	Ordinary, £1 1s.;	Journal, quarterly.
Manchester Geological Society, 1858 ..	Manch. Geol. Soc. ..	Mark Stirrup, F.G.S., 36, George Street, Manchester	216	None	£1.	Transactions, eight or nine parts per annum.
Manchester Statistical Society, 1833 ..	Manch. Stat. Soc. ..	25, Booth Street, Manchester. Francis E. M. Beardsall and G. H. Pownall	185	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick ..	320	1s. 6d.	3s. and 5s.	Report, annually.
Midland Union of Natural History Societies, 1877	Mid. Union	Dr. T. Stacey Wilson, Wyddrington, Edgbaston, Birmingham, and W. Wickam King, Pedmore House, Stourbridge	15 Societies.	—	3d. per Member	"Midland Naturalist,' monthly.
North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	670	None	21s. and 42s.	Transactions, about every two months.
North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	383	5s.	5s.	Report and Transactions, annually.
Northamptonshire Natural History Society and Field Club, 1876	N'ton N. H. Soc. ..	The Museum, Guildhall Road, Northampton. H. N. Dixon	200	None	10s.	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Nottingham Institute, 9, Shakespeare Street. F. R. Jackson	153	None	5s.	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. ..	J. Gardner, ?, County Place, Paisley	385	5s.	7s. 6d.	Report, annually.
Penzance Natural History and Antiquarian Society, 1839.	Penz. N. H. A. Soc. ..	G. F. Tregelles, 3, Market Place, Penzance	92	None	10s. 6d.	Report and Transactions, annually.
Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. ..	Tay Street, Perth. S. T. Ellison ..	294	2s. 6d.	5s. 6d.	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, 20, King Street South, Rochdale	244	None	6s.	Transactions, biennially.
Rochester Naturalists' Club, 1878 ..	Rochester N. C.	John Hepworth, Union Street, Rochester	162	None	3s. 6d., 5s., and 10s.	"Rochester Naturalist," quarterly.
Somersetshire Archæological and Natural History Society, 1849	Som'setsh. A.N.H. Soc.	The Castle, Taunton. F. T. Elworthy	554	10s. 6d.	10s. 6d.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc. ..	W. H. Finlay, Royal Observatory, Cape Town	75	None	£2.	Transactions, annually.
South London Microscopical and Natural History Club, 1871	S. London M. N. H. C. ..	Brixton Hall, Acre Lane, Brixton. H. Groves	110	None	10s.	Report, annually.
Tyneside Geographical Society, 1887 ..	Tyneside Geog. Soc. ..	Geographical Institute, Barras Bridge, Newcastle-upon-Tyne. G. E. T Smithson	1,200	None	10s.	Journal, half-yearly.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1892-93.—*Continued.*

Full Title and Date of Foundation.	Abbreviated Title.	Head-quarters or Name and Address of Secretary.	No. of Members.	Entrance Fee.	Annual Subscription.	Title and Frequency of Issue of Publications.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. ..	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	80	2s. 6d.	5s.	Proceedings, annually.
Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. ..	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	219	10s.	10s.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	James W. Davis, F.G.S., Chevinedge, Halifax	250	None	13s.	Proceedings, annually.
Yorkshire Naturalists' Union, 1861 ..	Yorks. Nat. Union ..	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds; Rev. E. P. Knubley, M.A., Staveley Rectory, Leeds; and Edgar R. Waite, F.L.S., The Museum, Leeds	462 and 2,488 Associates	None	10s. 6d.	Transactions, annually; "The Naturalist," monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. ..	Museum, York. T. S. Noble, F.G.S.	350	None	£2.	Report, annually.

INDEX OF THE MORE IMPORTANT PAPERS, AND ESPECIALLY THOSE REFERRING TO LOCAL SCIENTIFIC INVESTIGATIONS PUBLISHED BY THE ABOVE-NAMED SOCIETIES DURING THE YEAR ENDING JUNE 1, 1892.*

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Binns, G. J.	On Lightning in New Zealand Mines	N. Eng. Inst.	*Trans. Fed. Inst.*	3	415	1892
Brown, M. Walton ..	Report on the Experiments with Explosives at Elemore, Haswell, and South Hetton Collieries	Fed. Inst. Min. Eng. ..	*Trans.*	2	398	1891
" ..	Barometer and Thermometer Readings, 1890.	" " ..	"	3	556	1892
Drummond, D., and Hume, G. H.	Report on the Effects produced by the Explosives Roburite and Tonite ..	" " ..	"	2	385	1891
Stratton, T. H. M. ..	An Enquiry into the Cause of the Two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884	N. Eng. Inst.	*Trans. Fed. Inst.*	3	385	1892
Report of the Committee	An Investigation whether the Fumes produced from the use of Roburite and Tonite in Coal-mines are injurious to Health	Fed. Inst. Min. Eng. ..	*Trans*	2	368	1891
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* The Titles of Papers on other than Mining and Mechanical Engineering, etc., have not been reprinted.

Section B.—CHEMICAL SCIENCE.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Ashworth, J., and Prof. F. Clowes	The Detection of Fire-damp	Fed. Inst. Min. Eng.	*Trans.* ,,	2	352	1891
Bedson, Dr. P. P.	Reports on the Chemical Examination of the Fumes from the Explosives Roburite, Tonite, and Gunpowder	,, ,,	,,	,,	369, 388	,,
Bedson, Dr. P. P., and W. McConnell	Notes on the Gases enclosed in Coal and Coal-dust	N. Eng. Inst.	,,	3	307	1892
Brierley, J.	Hampshire Fuller's Earth	Hants. F. C.	*Proc.*	2	84	1891
Chicken, L. W.	Experiments with Explosives	N. Eng. Inst.	*Trans. Fed. Inst.*	3	88	1892
Dixon, Prof. H. B.	The Rate of Explosions in Gases	Fed. Inst. Min. Eng.	*Trans.*	,,	312	,,
Hall, H.	Coal-dust	,, ,,	,,	2	415	1891
Murday, T. J.	Fire-damp Detector	N. Eng. Inst.	*Trans. Fed. Inst.*	,,	469	,,
Orsman, W. J.	Notes on the Products and Temperature of Detonation of some High Explosives	,, ,,	,,	3	91	1892
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Section C.—GEOLOGY.

Barker, F.	The Fauld Gypsum Mines	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	1892
Beasley, H. C.	The Base of the Keuper in the Northern part of Wirral	Liv'pool Geol. Soc.	*Proc.*	VI.	248	1891
Bedford, J. E.	Evidence of Glacial Action near Leeds	Yorks. Geol. Poly. Soc.	,,	XII.	69	1892
Bell, D.	Notes on remarkable Glacial Mounds in Glen Fruin, Dumbartonshire	Glasgow Geol. Soc.	,,	IX.	—	,,
,, ,,	The Alleged Submergence in Scotland	,, ,,	,,	,,	—	,,
,, ,,	The Great Winter: a Chapter in Geology	Glasgow Phil. Soc.	,,	XXII.	261	1891
Beunie, J.	Scenes and Sections in Thornton Quarries in 1868	Glasgow Geol. Soc.	,,	IX.	—	1892
Bolton, H.	On the Finding of Marine Shells in the Boulder Clay of Bacup, Lancashire	Manch. Geol. Soc.	*Trans.*	XXI.	574	,,
Bonney, Prof. T. G.	The Permain Breccia of Leicestershire	Birm. N. H. M. Soc.	*Mid. Naturalist*	XV.	25	,,
Brodie, Rev. P. B.	On Certain Arachnids and Myriapods in the American and British Carboniferous Rocks, and their occasional Occurrence in other Newer Formations	Warw. N. A. F. C.	*Proc.*	36	29	,,
Brown, H. T.	Notes on a Summer Tour in Norway	Burt. N. H. Arch. Soc.	*Trans.*	II.	70	,,
Brownridge, C.	Our Walls and Pavements	Leeds Geol. Assoc.	,,	VI.	33	1891
Cadell, H. M.	Plant Remains in Olivine Basalt	Edinb Geol. Soc.	,,	191	191	1892
Carter, W. L.	The Geological History of England	Leeds Geol. Assoc.	,,	59	59	1891
,, ,,	The Life-history of a Volcano	,, ,,	,,	65	65	,,
,, ,,	Field Excursions	,, ,,	,,	79	79	,,
Chadwick, B.	The Yorkshire Boulder Committee and its Fourth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1892	155	1892
Cheetham, W.	A Geological Tour through Durham into Cumberland	Leeds Geol. Assoc.	*Trans.*	VI.	12	1891
Clark, W. F., and H. W. Hughes	A General Description of the South Staffordshire Coal-field South of the Bentley Fault, and the Methods of working the Ten-yard or Thick Coal	Fed. Inst. Min. Eng.	,,	3	25	1892
Clay, W. G.	Note on Mr. Dickson's paper on Moraines and Glacial Streams in the Valley of the Rhone and near Grindelwald	Liv'pool Geol. Soc.	*Proc.*	VI.	271	,,

Section C.—GEOLOGY.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Coates, H., and P. Macnair	The Rocks of Highland Perthshire: their Origin, Plication, and Denudation	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	221	1891
Cole, Rev. E. M.	The Erosion of the Yorkshire Coast	Yorks. Nat. Union	*The Naturalist*	For 1892	103	1892
Colenutt, G. W.	The Geology of the Isle of Wight	Hants. F. C.	*Proc.*	2	20	1891
Collins, J. H.	Notes on certain Illustrations of Sub-aerial Denudation due to Changes of Temperature	Cornw. R. Geol. Soc.	*Trans.*	XI.	375	1892
Cox, S. H.	The Coal-fields of Australasia	Fed. Inst. Min. Eng.	"	2	321	1891
Crick, W. D., and C. D. Sherborn	On some Liassic Foraminifera from Northamptonshire	N'ton N. H. Soc.	*Journal*	VI.	208	"
Dairon, J.	The Lower Carboniferous System in Dumfriesshire	Dum. Gal. N. H. A. Soc.	*Trans.*	7	103	"
Davis, J. W.	The Fossil Fishes of the Chalk	Leeds. Geol. Assoc.	"	VI.	9	"
" "	Bibliography, 1889-1890	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	119	1892
Dawkins, Prof. W. Boyd	The Channel Tunnel	Manch. Geol. Soc.	*Journal*	7	81	"
"	On the further Discovery of Coal at Dover and its Bearing on the Coal Question	" "	*Trans.*	XXI.	456	"
De Rance, C. E.	Further Notes on Triassic Borings	" "	"	"	478	"
" "	On the Underground Waters of Lincolnshire	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	22	"
Dickson, E.	Observations on Moraines and Glacial Streams in the Valley of the Rhone and near Grindelwald	Liv'pool Geol. Soc.	"	VI.	259	1891
Dougall, Prof. Jno.	The Leaf Caves of Mull	Glasgow Geol. Soc.	"	IX.	—	1892
Dow, R.	Tertiary Dykes of the Lower Tay Valley and District around Perth	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	226	1891
Eve, A. S.	Coombs and Lynchets	Marlb. Coll. N. H. Soc.	*Report*	XI.	89	1892
Fitzpatrick, J. J.	Report on the Field Meeting of the Society at a Section of the Coal-measures between Garswood and St. Helens	Liv'pool Geol. Soc.	*Proc.*	VI.	289	"
Forsyth, D.	The Geology of Cassphairn	Glasgow Geol. Soc.	"	IX.	—	"
French, J., W. H. Dalton, and H. W. Monckton	On the Occurrence of Westleton Beds in part of North-West Essex	Essex F. C.	*Essex Naturalist*	V.	210	1891
Geikie, Prof. J.	The supposed Causes of the Glacial Period	Edinb. Geol. Soc.	*Trans.*	VI.	209	1892
Goodchild, J. G.	Notes on some of the Limestones of Cumberland and Westmorland	Cumb. West Assoc.	"	XVI.	125	1891
Goodman, C. H.	Notes on the Geology of the Isle of Purbeck	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890-91	270	"
Gresley, W. S.	A Typical Section, taken in detail, of the 'Main Coal' of the Moira or Western Division of the Leicestershire and South Derbyshire Coal-field	Manch. Geol. Soc.	*Trans.*	XXI.	520	1892
Hardcastle, C. D.	Agates	Leeds Geol. Assoc.	"	VI.	43	1891
Harker, A.	Bibliography, Geology, and Palæontology, 1890	Yorks. Nat. Union	*The Naturalist*	For 1891	313	"
" "	Some North Country Quartzites	" "	"	For 1892	73	1892
Hawkesworth, E.	From Kettleness to Saltburn	Leeds Geol. Assoc.	*Trans.*	VI.	55	1891
Heddle, Prof. M. F.	On Pectolite and Okenite from new Localities; the former with new Appearances	Glasgow Geol. Soc.	*Proc.*	IX.	—	1892
Hick, T.	On the present state of our Knowledge of Yorkshire *Calamitæ*	Yorks. Geol. Poly. Soc.	"	XII.	1	"
Hinde, Dr. G. J.	Discovery of Chert containing Radiolaria, etc., in the Palæozoic Rocks	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890-91	253	1891
Hobson, B.	On the Igneous Rocks of the South of the Island, and Sections through Scarlet Point, with Plans	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	I.	337	1892
Holgate, B.	A long-buried Oak	Leeds Geol. Assoc.	*Trans.*	VI.	47	1891
" "	The Mode of Deposition and Properties of the Carboniferous Strata of Leeds and its immediate Suburbs	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	9	1892
Holland, P., and E. Dickson	Examination of Glacial Waters and Deposits from the Rhone Valley and near Grindelwald, and of Glacial Waters from near Chamounix	Liv'pool Geol. Soc.	"	VI.	322	"

Section C.—GEOLOGY.—*Continued.*

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Holmes, T. V.	Geology of Club's Voyage from Maldon to Chelmsford	Essex F. C.	*Essex Naturalist*	V.	197	1891
Holmes, W. M.	Glauconite Casts from Godstone Firestone	Croydon M. N. H. C.	*Proc. and Trans.*	For 1890-91	272	"
Hooze, J. A., R. A. Eekhout, and R. A. Van Sandick	The Coal-fields of Malaysia	Fed. Inst. Min. Eng.	*Trans.*	3	223	1892
Hopkinson, J.	Water and Water-supply, with special reference to the Supply of London from the Chalk of Hertfordshire	Herts. N. H. Soc.	"	VI.	129	1891
Horne, J.	Obituary Notice of Dr. J. Croll	Edinb. Geol. Soc.	"	"	171	1892
Hoskold, H. D.	Notes upon the Mines in the Argentine Republic, South America	N. Eng. Inst.	*Trans. Fed. Inst.*	3	418	"
Hughes, W. R.	Notes on the Severn Bore	Birm. N. H. M. Soc.	*Mid. Naturalist*	XV.	79	"
Jeffs, O. W.	In Memoriam: Daniel Mackintosh, F.G.S.	Yorks. Nat. Union	*The Naturalist*	For 1891	271	1891
Kidston, R.	Notes on some Fossil Plants from the Lancashire Coal-measures	Manch. Geol. Soc.	*Trans.*	XXI.	401	"
Kinahan, G. H.	S. W. Mayo and N.W. Galway Silurian Basin	Edinb. Geol. Soc.	"	VI.	155	1892
Kinnear, W. T.	*Homocanthus Borealis*	"	"	"	205	"
Lapworth, Prof. C.	Sketch of the Geology of the Birmingham District	Fed. Inst. Min. Eng.	"	3	10	"
Leighton, T.	On recent Discussions relating to the Geology of the South-East of England	S. London M. N. H. C.	*Report*	"	9	1891
Lewkowitsch, Dr. J.	The Physical Properties of Ice and Glaciers	Leeds Geol. Assoc.	*Trans.*	VI.	21	"
Liddell, J. M.	The Witwatersrandt Gold-fields	N. Eng. Inst.	*Trans. Fed. Inst.*	3	447	1892
Livett, Rev. G. M.	Local Buildings and Building Stones	Rochester N. C.	*Roch. Naturalist*	II.	33	1891
Lupton, A.	A Gold Mine, a Slate Mine, and a Salt Mine	Leeds Geol. Assoc.	*Trans.*	VI.	18	"
McLaren, D.	Notice of a reversed Fault	Glasgow Geol. Soc.	*Proc.*	IX.	—	1892
Marr, J. E.	The Backbone of England	Leeds Geol. Assoc.	*Trans.*	VI.	51	1891
Miller, Hugh	Landscape Geology	Edinb. Geol. Soc.	"	"	129	1892
Monckton, H. W.	Notes on the Glacial Formation near Chelmsford	Essex F. C.	*Essex Naturalist*	V.	191	1891
Morrison, W.	Old Red Outlier in Mid Ross	Edinb. Geol. Soc.	*Trans.*	VI.	188	1892
Morton, G. H.	Faulted Areas in the Country round Liverpool	Liv'pool Geol. Soc.	*Proc.*	"	294	"
" "	List of Papers on Local Geology since 1881	"	"	"	297	"
Murdoch, J. B.	Notes on the Culbin Sands, Morayshire	Glasgow Geol. Soc.	"	IX.	—	"
Nash, H. B.	The Unworked Coal-seams of Barnsley and District	Barnsley Nat. & Sci. Soc.	*Pamphlet*	"	—	"
Newton, E. T.	Note on the Occurrence of *Ammonites Jurensis* in the Ironstone of the Northampton Sands in the Neighbourhood of Northampton	N'ton N. H. Soc.	*Journal*	VI.	266	1891
Paul, J. D.	Recent Geological Notes	Leicester Lit. Phil. Soc.	*Trans.*	II.	405	"
Pearson, H. W.	Some of the Water-bearing Strata, and Wells sunk in same	Bristol Nat. Soc.	*Proc.*	VI.	327	"
Pike, E. R.	Mining in Perak, Straits Settlements	Corn. Min. Assoc. Inst.	*Trans.*	3	—	1892
Platnauer, H. M.	Notes on Two Borings	Yorks. Phil. Soc.	*Report*	For 1892	51	"
Postlethwaite, C.	The Cleaved Ashes and Breccias of the Volcanic Series of Borrowdale	Cumb. West. Assoc.	*Trans.*	XVI.	41	1891
Praeger, R. Ll.	On the Skull of an Irish Elk lately found at Belfast	Belfast Nat. F. C.	*Report and Proc.*	III.	416	1892
Reade, T. M.	The Trias of the Vale of Clwyd	Liv'pool Geol. Soc.	*Proc.*	VI.	278	"
" "	Notes on a Section of the Trias and Boulder Clay in Chapel Street, Liverpool	" "	"	"	316	"
" "	A further Note on the Decomposed Boulder and underlying Red Sandstone in the Chapel Street Section, Liverpool	" "	"	"	333	"
" "	Stalagmites of Sand	Yorks. Nat. Union	*The Naturalist*	For 1891	179	1891
" "	Sand Sculpture	" "	" "	For 1892	149	1892
Reid, A. S.	Sandpipes	E. Kent N. H. Soc.	*S. E. Naturalist*	I.	43	1891
" "	Concretions and Concretionary Actions	" "	" "	"	48	

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Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Reid, Jas.	Bones and Teeth found in Valley Drift of the River Stour	E. Kent N. H. Soc.	*S. E. Naturalist*	I.	51	1891
Richardson, C.	Landslips	Bristol Nat. Soc.	*Proc.*	VI.	301	"
Richardson, R.	Scottish Earthquakes of the present Century	Edinb. Geol. Soc.	*Trans.*	"	194	1892
Ricketts, Dr. C.	Some Phenomena which occurred during the Glacial Epoch	Liv'pool Geol. Soc.	*Proc.*	226		1891
Rosenbusch, Prof. H.	Note on the Metamorphosed Skiddaw Slates	Yorks. Nat. Union	*The Naturalist*	For 1892	119	1892
Seeley, Prof. H. G.	Some Scientific Results of a Mission to South Africa	S. African Phil. Soc.	*Trans.*	VI.	1	1891
Shore, T. W.	The Streams of Hampshire	Hants. F. C.	*Proc.*	2	33	"
Smith, John	"Torr's Warren," Wigtonshire	Glasgow Geol. Soc.	"	IX.	—	1892
Sopwith, A.	The Northern Part of the South Staffordshire Coal-field	Fed. Inst. Min. Eng.	*Trans.*	3	50	"
Sowerbutts, E.	Delegates' Report, British Association Meeting, Cardiff	Manch. Geog. Soc.	*Journal*	7	—	"
Spencer, Jas.	The Common Fossil Plants of the Coal-measures	Leeds Geol. Assoc.	"	VI.	34	1891
" "	On the Affinity of Dadoxylon to Cordaites	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	95	1892
Stirrup, M.	Earth Sculpture as illustrated in the Gorges of the Tarn and at Montpellier-le-Vieux, Southern France	Manch. Geog. Soc.	*Journal*	6	264	1891
" "	Delegates' Report, British Association Meeting, Cardiff	Manch. Geol. Soc.	*Trans.*	XXI.	352	"
Swanston, W.	A Fossiliferous Ironstone Nodule	Belfast Nat. F. C.	*Report and Proc.*	III.	401	1892
Tate, T.	A Geological Episode as recorded in the Ingleton Granite	Leeds Geol. Assoc.	*Trans.*	VI.	54	1891
" "	The Yorkshire Boulder Committee and its Fifth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1892	159	1892
Thomas, T. H.	A Visit to the Volcanoes of South Italy	Cardiff Nat. Soc.	*Trans.*	XXIII.	10	"
Thompson, Beeby	The Oolitic Rocks at Stowe-Nine-Churches	N'ton. N. H. Soc.	*Journal*	VI.	295	1891
Tute, Rev. J. S.	On a Permian Conglomerate Bed at Markington	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	72	1892
Usher, W. A. E.	Palæozoic Strata beneath Secondary Rocks, with special reference to the Prospect of obtaining Coal South of the Mendips	Som'setsh. A. N. H. Soc.	"	XXXVI.	82	1891
Vine, G. R.	Notes on some new or but little-known Eocene Polyzoa from Localities	Yorks. Geol. Poly. Soc.	"	XII.	52	1892
" "	British Palæozoic Ctenostomatous Polyzoa	" "	"	"	74	"
Walker, G. B.	Notes on the Coal-fields of New South Wales	Fed. Inst. Min. Eng.	*Trans.*	2	268	1891
Waller, T. H.	Note on some Ores from the Barrier Ranges, New South Wales	Birm. N. H. M. Soc.	*Mid. Naturalist*	XIV.	256	"
" "	A Week in North Wales	" "	"	XV.	109	1892
Wardle, T.	The Geology of the District round Worksop	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	For 1892	—	"
Whitaker, W.	Essex Well Sections: Part III.	Essex F. C.	*Essex Naturalist*	VI.	48	"
White, Jas.	A Glimpse of the Irish Highlands	Glasgow Geol. Soc.	*Proc.*	IX.	—	"
Wild, G.	On the Lower Coal-measures of Lancashire	Manch. Geol. Soc.	*Trans.*	XXI.	364	1891
Williamson, Prof. W. C.	On his earlier Palæontological Works	" "	"	"	488	1892
Winwood, Rev. H. H., and E. Wilson	Notes on the Life and Work of Charles Moore, F.G.S., with a List of the Fossil Types in the Bath Museum	Bath N. H. A. F. C.	*Proc.*	VII.	232	"
Woodward, A. S.	The Hybodont and Cestracionts Sharks of the Cretaceous Period	Yorks. Geol. Poly. Soc.	"	XII.	62	"
Woodward, H. B.	On the Geology of Crewkerne	Som'setsh. A. N. H. Soc.	"	XXXVII.	60	"
Worth, R. N.	The Succession of the Plymouth Devonians	Cornw. R. Geol. Soc.	*Trans.*	XI.	381	"
Young, Prof. J.	Notice of the late Sir A. C. Ramsay	Glasgow Geol. Soc.	*Proc.*	IX.	—	"
Young, R.	Geology of Main Drainage Works	Belfast N. H. Phil. Soc.	"	For 1891-92	89	"
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Section D.—BIOLOGY.

Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
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Section E.—GEOGRAPHY.

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Section F.—ECONOMIC SCIENCE AND STATISTICS.

Ashworth, Jas.	Notes on recent Accidents from Blasting in Coal-mines	Manch. Geol. Soc.	*Trans.*	XXI.	339	1891
Grundy, Jas.	On Accidents in Coal-mines	" "	"	"	439	1892
Munro, Prof. J. E. C.	On Wages and Hours of Working in the Coal Industry in France, Germany, and England	Manch. Stat. Soc.	"	For 1891-92	1	"
Smith, J. B.	On Colliery Depreciation	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	2	211	1891
Tonge, Jas.	The Future of Coal-mining	Manch. Geol. Soc.	*Trans.*	XXI.	329	"
*	*	*	*	*	*	*

Section G.—MECHANICAL SCIENCE.

Bigge, D. Selby	The Practical Transmission of Power by means of Electricity, and its Application to Mining Operations	N. Eng. Inst.	*Trans. Fed. Inst.*	3	278	1892
Brown, M. Walton	The Lee Alarm Water-gauge	" "	"	"	128	1891
" "	The Roberts Shot-firing Lamp	" "	"	"	129	"
" "	The Rateau Ventilator	" "	"	"	410	1892
" "	The Konig Differential Water-gauge	" "	"	"	452	"
Capell, Rev. G. M.	Notes on Fan Gauges in connexion with Fan Testing and the Adaptation of Fans to Mines; and Comparison of Fan and Furnace at Silverhill Colliery	Chesterf. Mid. Count. In.	"	III.	196	1891
Cochrane, W.	On a Duplex Arrangement of Centrifugal Ventilating Machines	N. Eng. Inst.	"	2	483	"
Cockson, C.	Notes on Mining Explosives	Manch. Geol. Soc.	*Trans.*	XXI.	235	"
Deacon, M.	Notes on Alfreton Colliery	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	III.	158	"
" "	Notes upon a small Electric Pumping Plant	" "	"	"	191	"
Foggin, W.	Locked Coil Wire Ropes	Fed. Inst. Min. Eng.	*Trans.*	2	261	"
Griffith, N. R.	Notes on the Sinking at Lens Collieries, No. 10 Pit, by the Poetsch System	" "	"	"	441	"
Gulbransen, P. F.	Difficulties about Pendulums	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	67	1892
Guthrie, J. K.	Pumping Appliances at Eltringham Colliery	N. Eng. Inst.	*Trans. Fed. Inst.*	2	457	1891
Hendy, J. C. B.	The Stanton Ironworks Company's Collieries	Chesterf. Mid. Count. In.	"	"	531	"
Holman, F.	An Old Mine Pump	Penz. N. H. A. Soc.	*Report and Trans.*	III.	—	1892

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Name of Author.	Title of Paper.	Abbreviated Title of Society.	Title of Publication.	Volume or Part.	Page.	Published.
Longden, J. A.	Presidential Address	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	2	513	1891
Macassey, L. L.	The proposed Channel Tunnel	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	44	1892
McLaren, John	The Economical Use of Steam in Colliery Engines	Fed. Inst. Min. Eng.	*Trans.*	2	344	1891
Marsh, F. S.	Germans (Fuzes)	Chesterf. Mid. Count. In.	*Trans. Fed. Inst.*	"	100	"
Mawson, R. B.	On an Apparatus for laying Coal-dust in Mines	Manch. Geol. Soc.	*Trans.*	XXI.	249	"
Orsman, W.	On the Detonation of High Explosives	" "	"	"	445	1892
Palmer, H.	Notes on an Electric Transmission Plant at East Howle Colliery	N. Eng. Inst.	*Trans. Fed. Inst.*	3	271	"
Speakman, J. J.	The Speakman Water Cartridge	Fed. Inst. Min. Eng.	*Trans.*	"	359	"
Sutcliffe, R.	A Sinking Machine and a new system of Sinking Pits	Manch. Geol. Soc.	"	XXI.	263	1891
" "	The practical working of Coal-cutting Machines	" "	"	"	563	1892
Swallow, R. T.	Description of a Method of removing Deposits from the Inside of Rising Main Pipes in Shafts	N. Eng. Inst.	*Trans. Fed. Inst.*	3	113	"
Wallis, T. M. W.	The Low-tension System of Shot-firing	Chesterf. Mid. Count. In.	"	2	553	1891
Workman, W.	Ventilation with Heating	Belfast N. H. Phil. Soc.	*Proc.*	For 1891-92	72	1892
Yates, J.	An Electrical Safety Apparatus for Cages	Fed. Inst. Min. Eng.	*Trans.*	2	362	1891

Section H.—ANTHROPOLOGY.

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II.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF FOREIGN SOCIETIES AND FOREIGN PUBLICATIONS.

ALUMINIUM IN THE UNITED STATES.

Aluminium. *By* W. R. INGALLS. *Engineering and Mining Journal (New York)*, 1892, *vol. liii.*, *pages* 5-6.

Bauxite occurs in Tennessee, Virginia, North and South Carolina, Georgia, Alabama, and Arkansas. Its discovery in the latter State was only announced in the early part of 1891 by Dr. J. C. Branner, State Geologist.* Bauxite, used in the manufacture of aluminium, is worth about £2 per ton at Pittsburg.

Cryolite is used in the manufacture of aluminium by the electric process. It is imported from Evigtok, near Arksut, Greenland, that being the only country in which the mineral is mined. The Evigtok mine is worked as a quarry 450 feet long, 150 feet wide, and 100 feet deep, while diamond drills have proved its existence to a depth of 150 feet deeper. The only place in the United States where cryolite is known to exist is at Pike's Peak, Colorado, but no workable deposits have yet been found.

Aluminium is generally produced by one of the electric smelting methods (the Cowles, Hall, Heroult, or Minet), which have almost entirely superseded the old sodium process. The bauxite is generally calcined with enough sodium carbonate to form sodium aluminate, and the incinerated mass is ground and leached with hot water, which dissolves the aluminate, leaving the silica and iron behind. The solution of sodium aluminate ($Na_2Al_2O_4$) is filtered, and the alumina (Al_2O_3) precipitated by carbonic acid gas is filtered, washed, and dried. The alumina is next dissolved in molten cryolite (Al_2F_6 + 6NaF) in pots and electrolysed, the apparatus and the details of the operation varying with the different processes.

J. W.

AMBER IN BURMA.

On the occurrence of Burmite, a new fossil Resin, from Upper Burma. *By* DR. FRITZ NOETLING. *Records of the Geological Survey of India*, 1893, *vol. xxvi.*, *pages* 31-40.

The amber of Burma, known as burmite, differs from ordinary amber (succinite) by containing no succinic acid. It occurs abundantly, but is of less value than common amber, on account of its colour and the occurrence in it of fissures filled with calcspar.

G. W. B.

AMBER AND JADE IN UPPER BURMA.

Preliminary Report on the Economic Resources of the Amber and Jade Mines Area in Upper Burma. *By* DR. FRITZ NOETLING. *Records of the Geological Survey of India*, 1892, *vol. xxv.*, *pages* 130-135.

The amber occurs in a soft blue clay, probably of Lower Miocene age. It is found in lumps of various sizes up to that of a man's head, and rounded, or flattened, in shape. The colour varies from light yellow to dark brown, and it is fluorescent.

Trans. Fuel. Inst., vol. iii., page 1067.

The jade mines are "pit mines" and "quarry mines." The former are situated on the banks of the river Uru, and the latter near the village of Tammaw. In the Tammaw mines the jade occurs as a vein in a blackish-green igneous rock. It is described as a "purely white cryptocrystalline mineral, much resembling the finest marble, containing here and there green specks of various sizes, which form the jade proper."

In the pit mines it occurs in boulders derived from other localities.

At least 500 men are engaged every season in working the quarry mines at Tammaw. The rock is heated by large fires, and, after cooling, is broken in pieces by hammers.

In the pit mines the miners simply dig a pit, and select boulders from the stuff dug out. Good jade is also sometimes found in the laterite.

The Report also contains a note on the Mogaung coal-field in the same area, which is of Tertiary age. G. W. B.

ASBESTOS.

The Chemical Composition of Asbestos. By J. T. DONALD. *Engineering and Mining Journal (New York)*, 1891, *vol. li., page* 741.

The following analyses show the composition of Italian and Canadian asbestos :—

	Italy.	Canada. Broughton.	Canada. Templeton.
Silica	40·30	40·57	40·52
Magnesia	43·37	41·50	42·05
Ferrous oxide... ...	·87	2·81	1·97
Alumina	2·27	·90	2·10
Water...	13·72	13·55	13·46
	100·53	99·33	100·10

Chemical analysis shows that the cause of the harshness of fibre of some varieties of asbestos is due to loss of water. J. W.

ASBESTOS MINING IN QUEBEC.

By R. W. ELLS. *Engineering and Mining Journal (New York)*, 1891, *vol. li., page* 498.

The asbestos mines of Quebec are practically the only deposits whose mineral is of a quality adapted for spinning and for the finer purposes of manufacture.

The asbestos veins are associated with rocks which for thirty years have been known as the Quebec Group. They comprise an extensive series of both sedimentary and igneous rocks, which extend from the Vermont boundary to the extremity of the Gaspé peninsula. Crossing the Gulf of St. Lawrence, the rocks also occur in Newfoundland, where specimens of asbestos have been found in course of geological explorations, although no systematic search has been made for the mineral.

Asbestos proper belongs to the hornblende or pyroxene (*sic*) group of minerals; while that of Quebec, commonly called asbestos, is really a variety of serpentine, known mineralogically as chrysotile. Sometimes these masses of serpentine assume such proportions as to rank almost as mountain-ridges.

Up to 1880, most of the fine asbestos fibre, for spinning, came from Italy and Corsica; it was hard to obtain, and of exceptionally fine quality, commanding as

high a price as £60 per ton. The discovery of the Quebec chrysotile, quite as well adapted for spinning as the Italian asbestos, almost revolutionized the industry, and has nearly closed the Italian mines.

So much of the serpentine of Quebec as is really asbestos-bearing to an extent which can be profitably worked, is confined to a comparatively limited area—in the townships of Thetford, Ireland, Coleraine, and Wolfestown, where succesful mining operations have been carried on for some years.

The veins of asbestos range from mere threads up to a thickness of 5 or 6 inches, though most of the workable veins do not exceed 2½ inches in width or length of fibre, and such veins of good quality and unbroken by partings of iron are regarded as extra No. 1 material. The asbestos veins occur throughout the mass of rock, and crop out where exposed; the mining is therefore simply open-quarry work, the entire rock being removed, broken up, and the veins of asbestos separated by hand-cobbing.

It has been estimated that the bulk of barren serpentine removed to obtain a ton of fibre varies from 25 to 1 on prolific ground to 50 to 1 on ordinary ground.

Little attention was paid to the occurrence of asbestos in Canada up to 1877, when the burning of the forests in Thetford and Coleraine townships laid bare the hills of serpentine. A French-Canadian named Fecteau observed the felting of the weathered asbestos, and the importance of the new material resulted in the operations of Ward Brothers, and later of the Johnson Asbestos Mining Company.

The output has increased from 50 tons in 1878 to about 8,000 tons in 1890. Sufficient study of these peculiar rocks has not yet been made to pronounce definitely upon their probable importance; but, when the deposits are made more accessible, considerable mining will undoubtedly be done, as these appear to be quite extensive. J. W.

JOINTED EARTH-AUGER FOR GEOLOGICAL EXPLORATIONS IN SOFT DEPOSITS.

By N. H. DARTON. *The Engineering and Mining Journal (New York)*, 1891, *vol. li., page* 401.

This auger consists of an auger-bit, a number of three-feet lengths of ¼ inch iron pipe, a cross-bar handle, all with threads and couplings for connexion to any length required; a pair of pipe tongs, and a receptacle of some kind. An ordinary 1½ inches carpenter's auger, with two or three whorls of double spirals, forms the bit; this is welded to a ½ inch iron bar to extend its length to three feet. The labour of working is not great, if care be taken not to bore too deeply at a time, and one man can make good progress in soft materials.

The instrument is said to be simple and inexpensive, and likely to prove useful in searching soft deposits at depths not exceeding 40 feet. J. W.

ON THE EXTENSION OF THE SAARBRÜCKEN COAL-FIELD INTO BAVARIA.

Ueber die Fortsetzung des Saarbrücker productiver Steinkohlengebirges in der Bayerischen Pfalz. By M. KLIVER. *Zeitschrift für das Berg-Hütten-und Salinen-Wesen, vol. xl., page* 471, *and plate* XVII.

The author discusses the probability of finding the Saarbrück coal formation in Bavaria. Elaborate details are given of the various coal-seams found by the boring experiments. W. F. W.

COAL-MINING IN HOLLAND.

Der Bergbau im Kænigreich der Niederlande. By FRANZ BÜTTGENBACH. *Berg- und Huettenmænnische Zeitung, vol. li., pages* 221-223.

The Dutch Government have granted concessions for the working of recently-discovered extensive coal-fields in the Province of Limburg, on condition that operations are commenced within a short period of time, and it may be expected that coal from this district will shortly take a prominent place in the market.

The Worm valley, on the frontier between Prussia and Holland, lies chiefly in the former country, but a small portion of it extends into Dutch territory, and contains the two coal-mines of Neuprik and Bleyerheide, now consolidated into one, and a third, called the Domanial mine, which is under Government control. The latter extends partly into Prussian territory, and by a singular treaty (concluded in 1816) may be worked across the frontier without interference from the Prussian mining authorities.

The coal is anthracitic, containing about 90 per cent. of carbon and 2·3 per cent. of ash, and yielding about 48 per cent. of large coal. It is excellent for household purposes, being very free from soot and smoke. The small coal is mixed with clay, and much used in stoves.

The Government mine is now let to the Aachen-Maastricht Railway Company, who raise about 200 tons per day, and employ 310 men.

The united Neuprik and Bleyerheide mine lies on Dutch territory, but is worked by a Prussian company. It is connected by a drift with the Neuvoccart mine across the frontier. At the frontier the drift is fitted with iron gates, locked, sealed, and placed under control of the Custom House officials.

The coal-mining district, with an area of 1,450 acres, is situated at and around the town of Limburg.

In addition to the coal-mines, Holland has at work, near Valkenburg and Maastricht, nine underground mines for building-stone, including the well-known one of St. Pietersberg.

Interesting particulars are given about the Miners' Mutual Aid Society, which is in a flourishing condition. The society grants pensions to those members who are over fifty years of age, and who have contributed to the funds for five years. The contributions amount to 3 per cent. of the wages. The society provides liberally in cases of sickness or accident, and the children of members receive free education. Contributions are regulated according to the time of membership and according to classes. The employer pays half the amount contributed by the workmen. The society has existed thirty-four years, and possesses funds to the amount of £1,168. The miners are also provided with good houses, and support co-operative stores.

A. R. L. AND W. F. W.

MARINE BEDS IN THE CRACOW COAL-MEASURES.

Ueber eine marine Einlagerung im productiven Carbon der Krakauer Gegend. By DR. E. TIETZE. *Verhandlungen der k. k. geologischen Reichsanstalt,* 1892, *pages* 76-77.

In 1891, two new shafts were sunk in the immediate neighbourhood of Tenczynek (mining district of Cracow); and, at a depth barely exceeding 42 feet from bank, a seam of gas coal, about 2 feet thick, was struck. The roof of the seam is formed by a band, about 4¼ inches thick, of bituminous shale, crowded with fossils; these, on examination, were found to consist entirely of the remains of *Lingula squami-*

formis, Phil. The same genus of brachiopod occurs in the Upper Silesian coal-field, and at Ostrau, in conjunction with a rich marine fauna ; but in those localities the genus *Lingula* is not represented in sufficient abundance to make its occurrence characteristic.

The find at Tenczynek appears to show that the Cracow Coal-measures are at a lower horizon than was heretofore generally suspected. It proves also the extension of marine conditions very nearly up to what is the presumed easterly limit of the coal-field. O. S. E.

THE DONETZ COAL-FIELD, RUSSIA.

Die Kohlenlager im Donetzki-Bassin in Russland. By N. SYRKIN. *Berg-und Huettenmænnische Zeitung, vol. li., pages* 203-204 *and* 241-243.

Russia produced 3½ million tons of coal in the year 1880, *i.e.*, less than 1 per cent. of the output of the world. In 1886, the output rose to about 5 million tons, and it is now still greater, but the production per head of the population remains less than one-sixth of that for the rest of the world.

At the same time scarcely any other country is so rich in coal. In Saghalien valuable seams occur, which, though worked in a small way, are too far from European centres of industry to become of importance. Near Kusnezk, in Western Siberia, thick seams of good quality lie unworked near the surface, timber being abundant in the neighbourhood and no centre of industry near. On both slopes of the Urals large coal-fields are known, but, although railways and rivers afford good facilities for transport, mining has made little progress there also.

The Khirghiz steppes and the Turkestan district are likewise rich, and geologists affirm that beds of coal stretch from the White Sea to the Sea of Azov. The coal-seams are mostly at considerable depths, but in many cases they are near the surface, and conveniently situated for working and exportation. Coal of rather poor quality occurs also in Poland, and is there extensively worked. The Caucasus Mountains are very rich in coal, and at Tkwibula, near Kutais, seams more than 15 feet thick lie near the surface, and within easy reach of the railway and the sea.

The richest of all the Russian coal-fields is the Donetz basin, which may some day come into active competition with England in the Mediterranean. It has a known area of 11,000 square miles, and future exploration may extend its limits still further. It has numerous seams lying near the surface and within depths of not more than 600 feet. These contain coal enough to supply the wants of the world at the present rates of consumption for fifty years to come, while the supplies at lower depths are doubtless much greater. In the shallow mines, which have hitherto been worked, explosive gas is unknown, and ventilation either by furnace or fan is unnecessary.

Anthracite occurs in the south and east of the district, smithy and coking coals in the west, and gas coal in the north, the latter being mostly used on the railways.

The district is considered by Prof. Mendelejew to be the richest in the world. The coal contains about 7 to 8 per cent. of ash, and sometimes as little as 2 to 3 per cent., with not more sulphur than English, and much less than Westphalian and Silesian coals. It contains little moisture, and when lying in heaps will not take fire spontaneously or crumble to small pieces. It can be worked at less cost than English or any other coal except that of Silesia, and, with the introduction of modern methods of working and a general development of industry, it may be expected to become cheaper in price.

The district is traversed by the Kursk-Charkov-Azov, the Woroneah-Rostov, the Ikaterinin, the Rostov-Wladikavkass, and Don railways, the last-mentioned, called also the coal railway, having branch lines over the whole district. In addition, the Donetz river, flowing for 400 miles through the richest coal country, admits of improvement for the passage of ships. A. R. L.

THE HERAKLEA COAL-FIELD, TURKEY IN ASIA.

Notice sur le Bassin Houiller d'Héraclée (Turquie d'Asie). By J. D'HARVENG. *Publications de la Société des Ingénieurs, etc., du Hainaut, third series, vol. i., pages* 278-314, *and two plates.*

The Heraklea coal-field extends along the shore of the Black Sea from Armutchuk, which is 7½ miles east of Heraklea, for a distance not yet exactly known. The author studied the general outline of the basin to a distance of 27 miles east of Armutchuk, or about 20 miles of the coal-field. The extent of the basin is probably at least 90 miles, and to the east it recedes from the sea. On the shore its known width at present does not exceed 1½ miles.

Twenty-five seams are worked having a united thickness of coal of 138 feet, or an average of 5½ feet, but the total number of workable seams is 42, of an average thickness of 3·38 feet. The coal-field is contorted, causing great variations in the inclination of the seams.

The existence of this coal-field has been known, and it has been worked to a very limited extent, from ancient times. Some impulse was given to its working during the Crimean War by the importation of miners to coal the British fleet. Since then working has been more extensive than formerly, but is still on a very limited scale, as the supply of labour appears to be insufficient. The natives have few wants and only require money to pay taxes, and for this purpose they are obliged by the Government to work in the mines, but during autumn and winter the supply of labour is irregular.

The method of working is most simple. When the seam is flat it is cut from the outcrop by two drifts 70 to 100 yards apart at different levels, so as to establish a ventilation; between these roads pillars are formed 20 to 35 yards square, until some slight difficulty arises, and then the pillars are drawn back and completely removed. In steep seams the same principle is applied, only the length of the pillar is reduced to 4 or 5 yards.

There are two collieries worked by shafts about 45 yards deep, and five by slopes with steam winches. The coal is carried from the working-places in panniers to the haulage-road, where it is emptied into tubs holding 2½ cwts., which are pushed to the outlet, and the coals tipped over screens.

The coal is taken from the mines by rail to the sea-shore and discharged at a wharf into caïques, which convey it to vessels, which cannot approach nearer than 330 yards to the shore. There is as yet no port whatever, but it has been proposed to form one at Cozlon or Yunguldak.

The coal-field of Heraklea is one of the sources of the civil list of the Sultan, and is under the charge of the Marine Minister. Concessions are readily granted, but only to Turkish subjects, a difficulty always easily surmounted by foreigners. Concessions are granted for ninety-nine years, subject to liability to dispossession on payment of compensation. A concession usually comprises a radius of 500 yards from a fixed point, and applies to one seam only. The administration of the civil list reserves all the small coal produced, and sells it. The coal being usually rather hard, the proportion of small does not exceed 25 per cent. On the rest of the

production 1s. 8d. per ton is paid. It is also provided that in case of pressing need, as in time of war, the Government may appropriate 60 per cent. of the large coal at the price of production.

The total production of the coal-field in 1890 was 76,000 tons, and in 1891 about 90,000 tons. The number of mines is about 105, but many of them produce little or no coal. Only one mine can produce 100 tons per day, and others produce 12,000, 10,000, 6,000, etc., tons per year.

As to consumers, the Government takes from 35,000 to 40,000 tons. Other consumers are the Ottoman and Balkan railways, steamboat companies, Constantinople and other towns. The coal is too bituminous to be good steam coal, but is used for that purpose because it is cheaper than Cardiff coal. W. N. A.

TENASSERIM COAL-FIELD, INDIA.

Coal on the Great Tenasserim River, Mergui District, Lower Burma. *By* T. W. H. HUGHES. *Records of the Geological Survey of India,* 1892, *vol. xxv., pages* 161–163.

This paper records the re-discovery of coal on the Great Tenasserim river, first announced by Dr. Oldham in 1855.

A seam cropping out on the banks of a tributary of this river has the following section :—

	Ft.	In.
Coal (A)	0	10
Shale	2	0
Coal (B)	2	3
Shale	3	0
Coal (C)	4	6

Three samples gave the following analyses :—

Specimens.	A	B	C
Moisture	15·20	10·80	11·34
Volatile matter	30·08	27·36	36·40
Fixed carbon	30·86	42·52	43·27
Ash	23·86	19·32	8·99
	100·00	100·00	100·00

Does not cake, and yields reddish brown ash.

Specimen C, from the bottom of the seam, is a hard jet-like variety, fitted to stand the wear and tear of transport, and containing little pyrites. The coal is above the average Indian coal, and when tested on the Government steam launch gave satisfactory results. The coal-field is unfortunately situated as regards labour and carriage, yet the writer estimates that on an output of 10,000 tons per annum it might be worked, and conveyed to Mergui, for something like 11s. per ton.

G. W. B.

DALTONGUNJ COAL-FIELD, INDIA.

Boring Exploration in the Daltongunj Coal-field, Palamow. *By* TOM D. LA TOUCHE. *Records of the Geological Survey of India,* 1891, *vol. xxiv., pages* 141-153, *and Map.*

The results are described of investigations of this coal-field by means of borings, made with the view of testing whether coal could be produced in sufficient quantities to warrant the construction of a railway, which would make it available for use in Upper India. It is concluded that it is extremely doubtful whether coal could be produced in sufficiently large quantities.

The coal-bearing rocks are of Karharbari age, and occupy an area of about 30 square miles.

Dr. Saise's estimate, of not less than 161,377,000 tons of coal with 11·7 per cent. of ash for this coal-field, is considered too favourable. Analysis shows that the coal contains more ash than is admissible in a serviceable coal. This, however, may be partly due to admixture with sand and clay during boring. G. W. B.

NORTHERN SHAN STATES COAL-FIELDS, INDIA.

Report on the Coal-fields in the Northern Shan States. By FRITZ NOETLING. *Records of the Geological Survey of India*, 1891, *vol. xxiv., pages* 99-119.

This paper is a preliminary description of certain coal-fields in the Northern Shan States. The coal is probably of late Tertiary age, but its exact position is uncertain. The seams vary from 2 inches to 30 feet in thickness, the average being 5 to 6 feet, the thin seams not being frequent. The following analyses are given :—

No. of Sample.	Description.	Volatile Matter and Moisture.	Fixed Carbon.	Ash.	Remarks.
1	Coal from Lashio, dull colour, very brittle...	66·75	24·05	9·20	Burns readily, with reddish ash.
2	Coal from Lashio, probably different from No. 2 seam...	54·48	35·44	10·08	Burns readily, with reddish ash.
3	Coal from Naleng (Lashio coal-fields)	33·18	33·06	12·46	Does not cake, not with vapour even (*sic*); ash dark red, contains much iron pyrites; 21·3 per cent. of moisture.
4	Coal from Namma seam (No. 1), of bright colour, but rather friable	56·82	38·58	4·60	
5	Coal from Namma seam (No. 2), of bright colour, but rather brittle	52·59	37·64	9·77	Average, with intervening earthy matter.
6	Coal from Namma seam (No. 3), of bright, jetty colour, hard, but laminated; best sample	60·45	36·15	3·40	Fracture glistening.
7	Coal from Namma seam (No. 4), of bright colour, but rather brittle	58·37	33·47	8·16	
8	Coal from Namma seam (No. 5), of bright colour, laminated, and brittle	56·08	34·08	9·84	
9	Coal from Hoetan-paipa, on the Namma stream, of bright colour; friable ...	53·49	35·12	11·39	
10	Coal from Namsale, a tributary of the Nampong; dull-looking	53·71	31·69	14·60	
11	Coal from Manzè seam (No. 1), of bright colour, very brittle; 6 inches seam ...	53·60	34·22	12·18	
12	Coal from Manzè seam (No. 2), dull-looking, brittle; 3 inches seam	55·42	34·94	9·64	

These coals form a very good fuel when fresh, and being hard would bear transport.

The coal of the Northern Shan States is very much poorer than that of the southern, yet it is more favourably situated for working.

The following coal-fields are mentioned:—1. The Lashio coal-field; 2. The Manzè-Namma coal-field; 3. Theinnimyo; 4. Namyaw Valley, near the village of Meungyaw; 5. Mansang and Meungpat; 6. Nong Hswan in Kyithi-Bansan State; 7. Silan on the Nammaw or Shwely river. Only the first two are described.

The writer's conclusion is that these coal-fields will be of no value so long as there are no means of transport by which the coals can be easily brought down the Irrawaddi river. Superficial accumulations will make sinking troublesome, and the climate predisposes to fever. G. W. B.

DARJILING COAL-FIELD, INDIA

Further Note on the Darjiling Coal Exploration. *By* P. N. Bose. *Records of the Geological Survey of India*, 1891, *vol. xxiv., pages* 212-217.

The result of this exploration is that no promising coal-seams have been discovered. G. W. B.

PROSPECTS OF GOLD, COAL, AND TIN IN THE MERGUI DISTRICT, INDIA.

Report on the Prospecting Operations, Mergui District, 1891-92. *By* T. W. H. Hughes. *Records of the Geological Survey of India*, 1893, *vol. xxvi., pages* 40-53.

This paper records the results of prospecting for tin, coal, and gold, confirms previous reports, and states that the tin deposits are sufficiently large and accessible to be worked profitably under economical management. The geological structure of the country, moreover, gives reason to hope that, both north and east of the district prospected, further paying tin deposits may be found.

The Tenasserim coal-field is estimated to contain 1,000,000 tons. The estimated cost on a yearly output of 10,000 tons is about 8s. per ton, transit from the coal-field to Mergui 2s. 10d. per ton, total, 10s. 10d. per ton. Other markets besides the local markets would be Rangoon and Penang.

Little is mentioned as to gold.

Appendices I. and II. contain the reports of Mr. R. Ross Clunis and Mr. Alexander Primrose respectively. G. W. B.

COAL IN THE FAR EAST.

Le Charbon en Extrême-Orient. *By* G. Fontaine. *Revue Maritime et Coloniale*, 1892, *vol. cxv., pages* 539-559.

The various Eastern countries visited by French men-of-war possess important resources of coal, which are being utilized to an increasing extent. East Asiatic coal is, however, always inferior to the European coals, giving a dense smoke and more ash, and as the quantity which can be burnt per hour is limited, the maximum speed obtainable is two or three-tenths less than with European coal.

Particulars of many of these sources of supply are given as follows:—

Saghalien.

Several mines are worked, producing generally lignite of good quality. Recently bituminous coal from this island, giving a calorific value of 0·8 as compared with Welsh coal, was procurable at Vladivostock at 37s. 6d. per ton.

Japan.

Numerous coal-basins exist in the islands of Yeso, Nippon, Shkoku, and Kushiu, and a great number of mines are worked. At the Tokio exhibition in 1890, samples were shown from nine different provinces.

In Yeso there are four basins of bituminous coal, the contents of which have been estimated at 400,000,000 tons. Hakodaté is supplied by the Pororai mines, the product from which sells at 27s. as against 56s. per ton for Cardiff coal, compared with which its calorific value is 0·8. As sold it is of large size, is very flaming, and lights easily.

Takashima is the largest coal-mine in the island of the same name, which has an output of 900 tons per day. The following is an analysis of the coal:—

Volatile matter	39·00
Fixed carbon	55·60
Ash	5·40
	100·00

It contains 0·081 per cent. of sulphur, less than is usual with Japanese coal, and costs 24s. 6d. per ton delivered at Nagasaki. The principal objections to the use of this coal are that it has too much dust and makes much smoke.

China.

China is said to possess coal-fields of enormous extent; that of Sechuen, in the interior, covering 250,000 square miles, but the production is small, and the quality of the products brought to the coast bad.

Formosa.

The basin of Kelung, on the north coast of Formosa, covers an area of 5,000 acres, and contains four beds, varying in thickness from 20 inches to 4½ feet. The output in 1882, when sickness put an end to the working, was 74,000 tons per annum. The works have since then been re-established, and the coal in 1889 sold at 24s. per ton.

East Indian Archipelago.

Borneo, Java, Sumatra, Cebou and other islands contain coal, which, however, does not appear to be actively worked.

Tonkin, etc.

Coal exists in several places, and is worked at Kebao and Turane, as to the product from which the following details are given:—

	Volatile Matter. Per Cent.	Fixed Carbon. Per Cent.	Ash. Per Cent.
Kebao ...	33·6 to 36·6 ...	59·2 to 61·8 ...	4·7
Turane ...	6 to 15 ...	74·6 to 77 ...	8 to 19·4

Both are anthracitic coals, and the latter in particular will not support combustion by itself.

The paper concludes with elaborate comparisons as to useful effect between these Eastern coals and other well-known products. G. E. C.

EARTHQUAKES IN ALGERIA.

Note sur les tremblements de terre en Algérie. *By* G. CHESNEAU. *Annales des Mines*, 1892, *series* 9, *vol. i.*, *pages* 5-46, *and plates I. and II.*

The author, a Government engineer, was apparently deputed by the French Ministry of Public Works in 1888 to study the question of earth-tremors in Algeria in connexion with the geological structure of the colony.

He gives a concise account of the shocks which have been recorded there between 1639 and 1888, the earthquake of 1790 being mentioned as especially disastrous. Of more recent earthquakes, those of 1867 and 1887 were the most violent.

It is pretty conclusively shown that the axiom laid down by Italian seismologists—viz., that in zones liable to earthquakes the direction of the strongest horizontal shocks is either perpendicular or parallel to the principal lines of fracture or plication in the strata of the country—is applicable to Algeria.

The character of the rocks is an important factor, both in the speed of propagation and in the dynamical effects of earth-tremors. Through thick deposits of drift or alluvium, for instance, the shock is transmitted with somewhat the same difficulty as a sound-wave through bran or sawdust. But a comparatively thin layer of sand or loam, resting on a more compact rock, behaves much as the vibrating sand-grains on a sounding-board.

Outcrops of crystalline and Palæozoic rocks are, comparatively speaking, seldom met with in Algeria; one notable exception is the patch of gneiss and schists on which the city of Algiers is built. A great band of Jurassic marls and limestones runs from west to east, partly concealed by newer strata. North and south of that strip appear the alternating clays and sandstones of the Gault, succeeded in their turn by Eocene, Miocene, Pliocene, and a vast extent of Quaternary deposits. The geological *résumé* is elucidated by a map which accompanies the original paper.

The author remarks in conclusion that most Algerian towns (excepting Algiers and Constantine) are, from the seismological standpoint, built on sites as ill-chosen as could possibly be. They stand indeed in the best cultivated districts of the dependency; now, these naturally irrigated, good arable lands are low-lying alluvial plains stretching along the base of mountain-ranges, forming just the kind of country which experience has shown to be the most exposed to seismic disturbances.

O. S. E.

ELECTRIC AUXILIARY HAULING-MOTOR.

By THOMSON VAN DEPOELE. *Electric Winding Engines for Mine Haulage. Engineering and Mining Journal (New York), vol. li., page* 659, *with illustration.*

In many cases where electricity is used for mine haulage it happens that there is only one steep grade on the line, without which it would be possible to use much smaller electric locomotives, or, it may be, after a plant has been installed, extension up a steeper grade is necessary. In such cases, an auxiliary stationary motor, set at the top of the hill, which could be operated from the same circuit as the locomotive, would overcome these difficulties.

The motor shown in the illustration was recently made for a Western coal-mine for this purpose. The outside dimensions of the hoist are 9 feet by 7 feet 4 inches, and the total height is nearly 6 feet. The motive-power is furnished by a Thomson-Houston motor of 35 horse-power, and wound for a potential of 440 volts. It is series-wound, and runs normally under load at a speed of 1,100 revolutions per minute. The speed from the motor-armature is reduced so as to give a rope-speed of

a little over 500 feet per minute. The drum, which is mounted on a sleeve and is thrown into action with the large gear by a friction-clutch, is 4 feet in diameter, with a 36-inches face. It is equipped with five controlling-levers, one of which operates the rheostat contact, one the drum clutch, two are brake levers, which are entirely independent one of the other, and the last throws the reversing-switch, giving the drum, when thrown into action with the motor, positive motion in either direction of rotation. J. W.

ACCIDENTS DUE TO FIRE-DAMP IN PRUSSIAN MINES DURING 1891.

Die im Jahre 1891 *auf den Steinkohlen-Bergwerken Preussens durch schlagende Wetter verursachten Unglücksfälle.* ANON. *Zeitschrift für das Berg-Hütten-und Salinen-Wesen im preussischen Staate, vol. xl., pages* 41-58.

During 1891, 104 fire-damp explosions—101 resulting in more or less serious injury to life and limb, 1 having no such results—occurred in 65 various collieries in the kingdom of Prussia. Of these explosions, 85 took place in the Lower Rhine-Ruhr coal-field, 5 in the Aix-la-Chapelle coal-field, 3 in that of Saarbrück, 7 in Lower Silesia, and 1 in the North German Wealden coal-mines. As mentioned elsewhere, 132 persons lost their lives thereby, 46 others were seriously injured, and 138 slightly hurt. It is noticeable that six fatal explosions (an average of one apiece) occurred in six mines of Lower Rhine-Ruhr, where the coal worked is apt to make much dust.

The immediate causes of explosion are classified as follows :—

	Cases.
Use of naked lights	11
Use of matches, tobacco pipes, etc.	5
Unauthorized opening of safety-lamps	7
Damaged condition of safety-lamps, or injury to same in course of use...	12
Sparks from soot or oil clinging to the gauze of the safety-lamp	1
Flame blown through gauze of safety-lamp by too great rapidity of air-current	5
Flame striking through gauze, owing to careless handling of safety-lamp	25
Shot-firing...	36

As to coal-dust, the state of the workings at the time of explosion is described as being damp in 24 cases, dry and not especially dusty in 58 cases, dry with more or less dust in 19 cases, and 1 case unknown. The worst explosion, causing 57 deaths, took place in a dusty mine. In 10 fatal explosions, one result of the accident was to coke the dust present in the mine.

As to atmospheric conditions, sudden changes took place in the barometer-level at the time of 7 explosions, change in air-temperature only in 1 case, and change both in air-temperature and barometer-level in 2 cases.

The greatest number of explosions occurred in March, and January was, as in previous years, an exceptionally unlucky month.

The origin of the fire-damp is ascribed to slow, continual streaming in of the gas in 58 cases, to secondary accumulations in 5 cases, to sudden fall of rock in 1 case, to blowers in 25 cases, to sudden issue from fissures in 10 cases, and from a borehole in 1 case ; the origin is unaccounted for in 2 cases.

To the above numbers must be added 4 cases of suffocation of miners by fire-damp in the Lower Rhine-Ruhr coal-field without the occurrence of an explosion. O. S. E.

THE FIRE IN THE FANNY-CHASSÉE COAL-PIT, LAURAHÜTTE, UPPER SILESIA.

Der Grubenbrand auf der Steinkohlengrube Fanny-Chassée bei Laurahütte O.-S. By— FIEBIG. *Zeitschr. für das Berg-Hütten-und Salinen-Wesen im Preuss. Staate*, 1892, *vol. xxxviii., pages* 291-295.

In the Fanny-Chassée coal-pit three seams are worked, being in ascending order :—

The Caroline seam	19½ to 24 feet thick.
The Glück seam	6½ feet thick, and
The Fanny seam	26 feet thick.

Between the two uppermost seams the barren rock is made up of strongly bituminous shales, with much pyrites, 13 feet in thickness; while between the Glück and the Caroline seams occur shales and square-jointed sandstones 82 feet thick. In all three coal-seams numerous fissures traverse the mass, filled with fine coal-dust.

The sinking of the shaft in the first years of this century was attended with considerable difficulties, owing to the many water-feeders and the unfavourable lie of the strata. These difficulties were presently complicated by the fire, which suddenly blazed up with great fierceness in the workings. At one time the fire was attributed to the masses of burning cinders from a waste-heap (of the neighbouring Glauben zincworks) which fell in with a portion of the measures on the breaking down of the pillars near the outcrop of the Fanny seam. Dams of timber and masonry plastered with lime proved ineffectual to arrest the fire, which forced its way through the fissures in the coal. Large areas were successively given up to the flames. Then spherical iron dams were used, and water conveyed from the surface by the help of steam-power was poured on to the workings behind the dams: but the pressure of the vast quantity of water thus ponded back broke through the dams and pillars, and the water itself, taking up the sulphureous products of combustion, became sufficiently acid to corrode the pumping gear.

Proceeding still on the assumption that the fire had been communicated by some means from aboveground to the goaf, the engineers left in all three seams a pillar of coal 11 feet thick standing right round the burning area, and in all headings meeting this pillar masonry-dams were built with great care. It now seemed that the fire had been effectually cut off, and in some places the coal was worked right up to the boundary pillar without any further interruption.

Suddenly, however, the flames burst forth in the Fanny seam, in a portion of the workings which had but lately been worked, and was entirely shut off from the old area of conflagration. It now became evident that the origin of the fire was not external, but was traceable to spontaneous combustion of the coal. Large masses of coal brought to day were, as an experiment, thrown together in great heaps; contrary to expectation, however, they did not burst into flame. Then it was pointed out that the fire had on no occasion originated in the Caroline seam, and experiments soon proved that the decomposition of the pyrites contained in the bituminous shales lying betwixt the two other seams was the true cause of the fire. This fact being placed beyond doubt, the methods of working and ventilation were altered; it was important that good use should be made of the sort of truce which intervenes between the opening up of a new district and the actual outbreak of fire. The workings are divided into smaller areas than formerly, and at certain points dams are built in the self-acting planes and in the bord-ways, leaving just the necessary openings for haulage and for passage of air-currents; bricks and mortar lie ready

to hand for stopping up these openings at short notice. The coal being so largely fissured, roof, floor, and working-face are plastered with mortar for considerable distances. Where small ventilating shafts are not found sufficient to secure a regular air-current, Körting's steam spray-injectors are used. If fire breaks out, it is soon circumscribed by the airtight dams, and dies down of itself for want of oxygen. When the thermometer on the hither side of the dam shows a sufficient fall of temperature, an opening is made, the noxious gases driven off by fresh air-currents, and the district examined with safety-lamps. All being well, the workings are carried on and continued till the next outbreak of fire. O. S. E.

ON THE ANALOGY IN MODE OF OCCURRENCE BETWEEN THE NATURAL GAS OF THE UNITED STATES AND FIRE-DAMP OF BELGIUM.

Sur les Analogies de Gisement du Gaz Naturel aux Etats-Unis et du Grisou en Belgique. By — LOHEST. *Annales de la Société Géologique de Belgique, vol. xix., pages* 44-47.

In the United States, gas and petroleum occur in anticlinal folds; in the Belgian coal-fields, plicated strata contain the most fire-damp. In the Mons basin, for example, the southern portion, where the structure is very complex, is subject to instantaneous disengagements of fire-damp. Towards the north of the basin, however, where the beds lie flat, there is little fire-damp. Similarly, in the Liége basin, fire-damp is most abundant where the strata are most disturbed. The roofs of the coal-seams are compared with the impermeable shales which cover the porous gas-yielding limestones, and the coal itself, fractured and full of joints, to the latter.

While the author thus thinks it possible that the fire-damp may be concentrated in the anticlinal folds, as in America, he admits the difficulty that the fractures of such folded beds would tend to facilitate the escape of the gas, while in the horizontal strata it might rather be expected to be retained.* G. W. B.

A FIRE-DAMP INDICATOR.

Note sur un Nouvel Indicateur de Grisou. By G. CHESNEAU. *Annales des Mines, series* 9, *vol. ii., pages* 203-221, *and* 2 *plates.*

Mr. Chesneau, after describing the dangers and inconveniences connected with the use of the Pieler alcohol lamp and of different improved models of that lamp, describes an alcohol lamp of his own invention.

It is composed of a brass reservoir for the alcohol, surmounted by a circular crown for the admission of air (which can be regulated) through double gauzes. Resting on the crown and surrounding the wick-tube is a solid cylinder of sheet-iron which serves as a screen. Above this screen, and resting on it, is an iron-wire gauze 5½ inches high. The gauze is surrounded by a sheet-iron shield furnished with an observing-window, completely closed by a sheet of mica, on which a scale is engraved. The shield is fitted at its base with an annular diaphragm which closely surrounds the base of the gauze so that the exterior air can never arrive directly to the gauze. The diaphragm rests on an asbestos washer for the purpose of diminishing the heating of the lower part of the lamp when it is in a gaseous mixture and the shield gets hot. The top of the shield is furnished with openings protected by

* [But if fire-damp be a consequence of partial distillation of coal, its presence in disturbed strata is easily accounted for, as being the result of the heat produced by thrusting and folding.—ED.]

screens to prevent currents striking the gauze. An outer movable screen of sheet-iron having a window, protects, when required, the base of the observation-window in the shield against currents, and this prevents the deposit of dew which tends to form on the interior of the mica by outside cooling.

To make an observation, it suffices to bring the window in the movable outer shield in front of the mica observation-window. In a calm atmosphere the dew disappears of itself some minutes after lighting, and only re-forms when the lamp is brought into a cold current.

The interior of the reservoir contains a small piece of cottonwool under the wick-tube to prevent the rapid escape of alcohol if the lamp is overturned. When the reservoir of the ordinary Pieler lamp is tightly packed with cottonwool it only gives a cap in gaseous mixtures for some minutes, because the alcohol retained by the cotton ascends the wick with difficulty, and the flame soon lowers, and the wick carbonizes. The almost total suppression of the cottonwool in the new lamp offers no danger, because the lamp goes out, when laid horizontally, before the alcohol can spread in the lamp. It is not so with the ordinary Pieler lamp, where the alcohol can spread and burn on the gauze when they are filled and much inclined. The alcohol is introduced by a hole, fitted by a screw, a tight joint being obtained by means of a washer of lead or leather. The weight of the lamp, full of alcohol, is 3·2 lbs.

The entry of the air and the exit of the products of combustion being absolutely separate in the new indicator there can be no mixture between them as in the Pieler lamp, in which air charged with gas may come in and burn in the whole height of the gauze and heat it strongly. Placed in stationary gaseous mixtures of increasing percentages, the lamp gives caps which only reach the top of the gauze with about 3 per cent. with the alcohol flame regulation adopted. With from 3 to 5·5 per cent. the alcohol flame elongates, the cap enlarges, becomes cylindrical, but lowers more and more from the summit, the lamp being unable to emit the increasing products of combustion. A little above 5·75 per cent., the alcohol flame elongates towards the top of the gauze, but without sensibly heating it, the quantity of air drawn in being insufficient for the complete combustion of the gas, and the alcoholic vapour liberated by the heating of the lamp. Above 5·75 per cent. (proportion inferior to the limit of inflammability of air and fire-damp, which is produced with 6·1 per cent.) all flame disappears in the lamp, and the gas burns with a very paleflame in the crown only without considerably heating the reservoir. All is extinguished after some seconds very rapidly if the inlet regulator is closed. The alcohol flame of the lamp reduces rapidly to its initial height when removed to pure air. Tested in explosive currents the lamp appeared as safe as ordinary safety-lamps of good construction.

The height of the caps vary considerably according to the volatility of the alcohol employed, and to obtain comparable results the same alcohol must be used. The alcohol giving the best results is wood spirit or methylated alcohol of 92·5 degs. by the Gay-Lussac alcohol-meter at 59 degs. Fahr. To increase the visibility of the caps, chloride of copper may be dissolved in the alcohol with a little hydrochloric acid to maintain it in solution. The proportion recommended is about 17 drops of a saturated solution of crystallized chloride of copper in concentrated hydrochloric acid per pint of alcohol; this gives the alcohol flame a green tinge. In this way caps may be seen with from 0·1 to 0·2 per cent of fire-damp. They are easily seen with 0·5 per cent. or more,

The proper methods of regulating the alcohol flame and the appearance of the caps are minutely described. W. N. A.

CLASSIFICATION OF ORE-DEPOSITS.

By J. F. KEMP. *School of Mines Quarterly (New York), vol. xiv., pages* 8-24.

This paper gives a *résumé* of the various attempts at the classification of ore-deposits which have from time to time been made, from von Cotta downwards. The author decides in favour of schemes based entirely on origin, as opposed to those which depend more or less completely on form or character of filling; and proposes a detailed classification which divides ore-deposits into four classes, viz. :—(*a*) Of igneous origin ; (*b*) deposited from solution ; (*c*) deposited from suspension ; (*d*) of indeterminate origin. These classes, especially (*b*), are of course largely subdivided. G. E. C.

THE ORIGIN OF CALAMINE-DEPOSITS.

Note sur l'Origine des Gîtes Calaminaires. By A. LODIN. *Bulletin de la Société Géologique de France, series* 3, *vol. xix., pages* 783-793.

The author first points out that two theories have been successively proposed to account for the origin of the deposits of carbonate, hydrated carbonate, and anhydrous (or, as the case may be, hydrated) silicate of zinc, collectively known to miners as calamine. The oldest theory postulates the derivation of these ores from pre-existing sulphides, altered by atmospheric agency. This hypothesis is based on the almost constant occurrence, in the deposits, of blende, galena, and pyrites, in a quantity which increases directly as the depth from the surface.

The other theory, originated by Elie de Beaumont and developed by Delanoue, postulates the uprise of acid waters containing zinc in solution, which is deposited on contact with limestone. In that case, the presence of blende and the accompanying sulphides would be due to the reduction and sulphurization of oxydic ores by organic matter. One of the chief arguments adduced in support of this theory was the presumed refractoriness of blende to atmospheric agencies, but facts do not accord with this presumption : thus, at the Pontpéan mine, some heaps of blende which have been exposed to the air for about a century have finally lost all their zinc, leaving only a plumbiferous and argentiferous residue.

The author's study of several calamine-deposits, combined with a series of experiments, leads him to reject absolutely the last-mentioned theory and to confirm the older hypothesis. He draws attention to the occurrence of calamine as being exclusively in calcareous rocks, never in siliceous or alumino-siliceous rocks, and concludes that the deposition of the ore is due to chemical precipitation by calcium carbonate. He describes in detail the principal features of a calamine-deposit, taking as examples those of Sardinia, and points out that their constitution is closely connected with the actual surface-features of the district and with the mean level of the underground waters (*la nappe souterraine*).

The reaction of water, holding oxygen in solution, on blende-galena deposits produces (*a*) ferric hyposulphate and lead sulphate, (*b*) zinc sulphate and sulphuric acid. Group *a* remains *in situ*, and is gradually decomposed by the action of oxygenated and calcareous waters into iron oxide and lead carbonate ; while group *b* tends to percolate downward through the rocks.

Now zinc sulphate in concentrated solution is precipitated by calcium carbonate, the results of the reaction being a mixture of hydrated calcium sulphate and zinc hydrocarbonate (hydrozincite). The experimental difficulties of producing also the anhydrous carbonate (Smithsonite), which occurs in conjunction with hydrozincite in calamine-deposits, appear to be insuperable so far, but its occurrence in nature may be explained as follows :—

1.—Presence of a large excess of sulphuric acid or of very acid ferric sulphate; consequent formation of gypsum and absorption of sufficient water to prevent the formation of hydrocarbonate.

2.—Presence of carbonic acid gas at a sufficient tension to prevent the hydration of the anhydrous carbonate by water in excess. (At the calamine mines of Malines, in the Department of the Gard, carbon dioxide often comes off in such quantities in the neighbourhood of great masses of calamine and blende that the work of quarrying through the limestone to get at the ore has to be suspended for a few days).

3.—Dissolution of the hydrocarbonate in water holding carbonic acid in excess, then precipitation (from this solution) of the anhydrous carbonate by excess of calcium carbonate. To this reaction the author would largely attribute the origin of the veins of pure Smithsonite which are often found in the hanging and foot-walls of the deposits.

As to magnesian limestones, the author found that giobertite (natural carbonate of magnesia) gave no precipitate with a sulphate of zinc solution; but powdered dolomite, after a prolonged contact, gave a very feeble precipitate.

The origin of the silicates in calamine-deposits is no doubt due to the presence of hydrated or combined silica in the limestones, which are acted upon by the sulphate of zinc; and, given that condition, the author considers the formation of zinc silicate just as easy of explanation as the formation of zinc hydrocarbonate.

O. S. E.

THE PERSISTENCE OF ORES IN LODES IN DEPTH.

By Wm. P. Blake. *Engineering and Mining Journal (New York), vol. lv., page* 3.

Prof. Blake discusses the question of the relative mineralization of lodes at great and shallow depths, in the light of increasing evidence that it has been effected, in the majority of cases, by lateral secretion. The presumption is that the solvent action and movement of the solutions would be greatest comparatively near the surface, yet this does not necessarily affect the mineralization, as cases are cited of lodes which in depth have changed from wet to dry, without any falling off in the productiveness of the lodes. In the Butte district there are sometimes evidences of active oxidation far below the water-level; and there is no ultimate tendency to decreasing richness in depth.

Apart from the outcrops of lodes, which are affected by special climatic and other agencies referred to in detail, the conclusion is that, in a homogeneous country-rock, the productiveness of lodes may be expected to continue to as great a depth as is likely to be reached in practice.

G. E. C.

FLORA AND FAUNA OF THE BELGIAN COAL-MEASURES.

Matériaux pour la flore et la faune du houiller de Belgique. Par X. Stainier. *Annales de la Société Géologique de Belgique, vol xix., pages* 333-359.

The author points out the importance of a knowledge of the flora and fauna in the study of the origin of coal, and in the practical question of the correlation of seams.

An important result of the investigation is the establishment of the fact of the abundance of fish-remains in the Belgian coal-field, as hitherto they have been rarely recorded. The roofs of many of the coal seams contain numerous scales and other remains. One is described as a veritable bone-bed. It occurs over the first

workable seam in the Upper Coal-measures, and the author suggests its correlation with the bone-bed in Yorkshire.

A table of fossils, classified according to their horizons in the Coal-measures, is given.

In the Sainte-Barbe seam, calcareous nodules containing *Goniatites* (*diadema*, and *Listeri*) are found. Some of these Goniatites contain carbonaceous matter. The presence of marine—or even pelagic—organisms, such as Goniatites, in the very midst of a coal-seam, is important in connexion with theories of the origin of coal.*

G. W. B.

MINERAL DEPOSITS OF THE CAUCASUS.

Note sur les Principaux Gisements Minéraux de la Région du Caucase. By — LEPROUX. *Annales des Mines, series* 9, *vol. ii., pages* 491-540, *and plate XIII.*

The mountain-chain of the Caucasus, formed near the end of the Tertiary period, runs about west-north-west to east-south-east. Between it and the Anti-Caucasus to the south there are two main valleys sloping to the Caspian and Black Sea respectively. In these a series of Tertiary formations are developed, covered towards the Caspian by loess. The Tertiary rocks are succeeded by some little-developed cretaceous beds; next come Jurassic rocks, often traversed by sheets of diabase and melaphyre; and then a considerable thickness of Palæozoic clay-slates of doubtful age, which rise to the north and south against the crystalline rocks forming the axis of the chain.

Iron.—This is fairly abundant, but too far from the coast for export; and the extensive destruction of the forests, and the scarcity and poor quality of the coal, render smelting impossible, unless petroleum can be utilized.

Manganese.—The deposits are of considerable importance, especially those on the river Kvirilla in the district of Charopan, where the mineral-bearing country comprises an area of 130 square kilometres. The beds, accompanied by limestone and sandstone of the Upper Eocene, rest on the Upper Chalk. All have remained horizontal, and are well exposed in section by the deep valleys of the Kvirilla and its affluents.

The following analyses, among others, are given:—

Manganese	54·86 ...	59·05
Oxygen (combined with manganese) ...	31·84 ...	24·25
Iron	1·50 ...	1·00
Waste	11·80 ...	5·70

The average Kvirilla ores give 55 per cent. of manganese, 0·15 to 0·20 per cent. of phosphorus, and 2 to 6 per cent. of silica.

The production has been approximately as follows:—

	Tons.		Tons.
1884 ..	17,000 ...	1887 ...	53,000
1885 ...	56,000 ...	1888 ...	30,000
1886 ...	68,000 ...	1889 ...	70,000

The cost of raising is stated as 7s. 6d. per ton, and transport from the mine to Kvirilla station 21s. per ton.

Cobalt.—Several deposits of cobaltine exist in the government of Yélizavetpol, of which the most important is that of Daschkessan. This occurs under a sheet of diabase carying much oxide of iron; the cobaltine is contained in the rock forming the wall, together with garnets and copper pyrites.

[* Marine organisms may be washed up on to a beach or into an estuarine sandbank or marsh after great storms in fair abundance. Nodules prove nothing as to where the organisms lived.—ED.]

Lead and Silver.—Many lodes carrying argentiferous galena traverse the crystalline rocks forming the axis of the chain and the Palæozoic rocks immediately above them, but the only mines of any importance are those of Sadone, near Vladikavkaz. These produced, in 1888, 5,660 tons of mineral containing 0·02 per cent. of silver, 6 to 7 per cent. of lead, and 0·06 per cent. of copper. They belong to the Government, and the ores are treated near by.

Zinc.—Only one mine is being worked, that of Khot-Eli, south of Batoum, the ore from which runs 12 per cent. of zinc and 6 per cent. of copper, but only 125 tons were exported in 1888.

Copper.—A great many deposits of copper are known throughout the Caucasus, the most important of which are those of Alverdski, Kedabek, and Zangezour, on the north side of the Anti-Caucasus, in the Governments of Tiflis and Yélizavetpol. These deposits are rich, but situated in a very difficult and elevated region, where the only fuel obtainable is petroleum residue, which at Kedabek costs considerably over £3 per ton.

The deposit of Alverdski appears to be a large irregular mass at the contact between diabase and quartzite. The ore consists of copper pyrites, grey copper and erubescite, in a gangue of iron pyrites and gypsum, and varies in percentage from 8 to 25, with an average of 10 per cent.

The deposits at Kedabek are also irregular masses, the nature of which is not definitely indicated. They are composed of a quartzose rock sprinkled with pyrites and black oxide of copper.

The following analyses, among others, are given :—

	Upper Mass. Large Grains.	Karl-stock Average.	Arnold-stock. Rich Ore.	50 yards, south of Upper Mass. Average.
Silver	0·02	—	—	—
Copper	13·32	9·29	22·05	7·12
Iron	34·38	15·66	14·31	25·92
Zinc	—	1·87	5·82	5·10
Sulphur	38·85	22·32	23·74	25·80
Insoluble matter	11·29	46·46	30·38	15·25
Manganese, antimony, etc.	3·12	—	—	—

The deposits of Zangezour, near the Persian frontier, consist of a breccia about 2 feet thick, at the contact between granitic syenite and diorite, both of which are mineralized. It contains granite cemented by a ferruginous clay, both carrying malachite, copper oxide, native copper, etc., the average copper contents of the whole being about 10 per cent.

The total production of copper was 1,500 tons in 1889. In 1838, it was 24,000 tons of ore.

Gold has been found *in situ* in a few places, and in the gravels of some of the rivers, but never in workable quantity.

Petroleum.—Deposits exist all round the Caucasus chain where it merges into the low country, but are of most importance at the two extremities, the peninsulas of Tamansk and Apscheron, especially the latter, where the Baku wells are world-famous. The petroleum is generally, though not exclusively, found in the Upper Tertiary series.

Contrary to the generality of Caucasian petroleum, that of the Tamansk peninsula is light (density 0·755 to 0·825). It is contained in thick beds of clayey sand of Tertiary age, and is very irregular in distribution. In the region to the south, the petroleum is heavy and thick (density 0·945 to 0·985).

The Baku deposits are practically confined to the Apscheron peninsula, the formation of which is entirely Tertiary and post-Tertiary; and are generally found in the southern and eastern portions of the anticlinal folds. The petroleum is usually oily and thick, of brown or black colour, but there are great differences in the density. In some cases it is accompanied by salt water, the absence in which of bromine and iodine indicates that it does not come from the Caspian, as had been supposed. The total production for the region was 3,316,004 tons in 1889, of which 3,282,633 tons was from Baku.

Coal.—Coal-beds are very numerous, being found almost wherever the Jurassic formation crops out, but they are thin and of poor quality. A number of localities are described.

The total production in 1888 was 8,522 tons, including lignite, etc. G. E. C.

THE MINERAL POVERTY OF WESTERN BORNEO.

Notes Recueillies au Cours d'une Exploration dans l'Île de Bornéo. By — CHAPER. *Bulletin de la Société Géologique de France, series* 3, *vol. xix., pages* 877-882.

The author went up the great river Kapoeas on a trading steamer from Pontianak to Sintang (240 miles), and then in boats manned by natives to Semitau (72 miles). The banks are low and apparently made up of yellowish clay; indeed, the whole plain-country is covered by a deposit of fine clay (about 14 feet thick), and this extends up the hillsides to the 200 feet level. Below the clay are yellowish sandstones and soft shales, with which are intercalated two or three bands of hard conglomerate. Near Mounts Oejan and Rajoen, the rocks are intensely metamorphosed into quartzite, jasper, and dark green diorite with garnets. In both the Kapoeas and Sebroeang valleys there are below the clay deposits of very fine white auriferous and diamantiferous sand. Some of these deposits are still washed for gold by natives and Chinamen, but the profits are comparatively small. As to diamonds, the author purchased three at a high price at Samarangaï, but there is strong reason to believe that they had been brought to Borneo from some other country. Lignites of fairly good quality occur in plastic clay in the Knapei Valley and at Selimbau, in localities which are under water in the rainy season. At Blietang there are several bands of lignite, one of which is said to be 15 or 16 feet thick; but here also, the seams are under water when the river is high.

To sum up, that part of Western Borneo which came under the author's observation appears to offer little scope for industrial enterprise; and the chief hopes of explorers must be directed to the still unknown, mountainous centre of the island.

O. S. E.

ECONOMIC RESOURCES OF SIKKIM.

Notes on the Geology and Mineral Resources of Sikkim. By P. N. BOSE. *Records of the Geological Survey of India, vol. xxiv., pages* 217-230, and map.

The mineral wealth of the district consists chiefly of copper ores. They occur in a series of rocks known as the Daling Group, and are disseminated through the schists and slates in bands and veins parallel to the bedding. In one case a true lode occurs. The ore is copper pyrites, often accompanied by mundic. Traces of sulphate, carbonate, and oxide of copper frequently occur as the result of the alteration of the pyrites. The gangue is shale hardened by the infiltration of quartz, or of quartz alone. In the junction-beds and in the underlying gneiss

itself, copper is also found, but the ores are less rich. In the Daling Group the richest ores occur in greenish-grey, rather soft slaty shales. The ores are worked by the natives, but, owing to their primitive methods, they are compelled to abandon their mines as soon as they get to a certain depth, on account of the volume of water. With improved appliances, the deeper, and apparently richer, deposits could be reached.

Analysis of a sample of ore taken at random from one of the workings gave 20·31 per cent. of copper. An average sample from another working gave 12·21 per cent. Picked ore from the Ráthokháne locality was found by Mr. Mallet to contain 8 or 9 per cent. G. W. B.

SWAMP OAK AND NIANGALA GOLD-FIELDS, NEW SOUTH WALES.

Geological Notes on the Swamp Oak and Niangala Gold-fields. By G. A. STONIER. *Records of the Geological Survey of New South Wales, vol. iii., pages* 60-68.

The Swamp Oak gold-field is situated about 25 miles east of Tamworth, New South Wales, and that of Niangala 9 miles farther south-east, a little west of the watershed of the Great Dividing Range.

Alluvial gold has been found since 1852 in Swamp Oak Creek, and there is auriferous Tertiary alluvium, overlaid by basalt, at Niangala, which, however, has been little tested as yet.

The gold-bearing reefs are contained in Lower Carboniferous mudstones; the whole series is seamed with quartz, but the veins only carry gold in the vicinity of diorite-dykes, which occur in a well-marked axis of upheaval which has probably occasioned the veins.

The auriferous belt at Swamp Oak is 2¼ miles long and 1½ miles wide. The reefs cannot be traced any distance—this being apparently due to closing of the walls and not to complicated faulting. They mostly dip towards the dyke. They all carry mispickel in isolated crystals, averaging 1½ per cent. of the bulk. Iron pyrites is exceptional. The gold is fine, and mostly in combination with the mispickel. So far as the district has been opened out the gold seems to run in shoots, not, as a rule, exceeding 20 feet in width. The average thickness is 9 inches to 1 foot, the veins themselves running up to 3 feet. The distance between the shoots and their dip vary considerably.

The Niangala district appears to resemble that of Swamp Oak in general character. G. E. C.

GRAPHITE FROM CEYLON.

On Veins of Graphite in Decomposed Gneiss (Laterite) in Ceylon. By DR. JOHANNES WALTHER, *translated by* R. B. FOOTE. *Records of the Geological Survey of India, vol. xxiv., pages* 42-45.

The most important mineral export from Ceylon is graphite. In the virgin forests mighty domes of grey gneiss weathered to a depth of 39 feet, and soft enough to be cut with a knife, occur. In this decomposed gneiss, or laterite, many branched veins of graphite are found. The main veins are from 4½ to 8½ inches in thickness. As to the origin of the graphite, it is supposed that the fissures originated in the unweathered gneiss by dislocations, and that they were afterwards filled by sublimation of some hydrocarbon rich in carbon. G. W. B.

THE OFOTÈN RAILWAY, AND THE IRON-ORE DEPOSITS OF SWEDISH LAPLAND.

Ofotenbanen og Jernmalmfelterne i Svensk Lapmarken. *By* Prof. AMUND HELLAND. *Norsk Teknisk Tidsskrift, vol. x., pages* 1 *to* 13, *and two plates.*

As is well known, all work on the Ofoten-Luleä railway, projected to open up these deposits, is now stopped, and the English company which held the concession has forfeited it. The section from Gellivare to Luleä, on which a large amount of work has been done, will probably be taken over and finished by the Swedish Government. The parliament has already granted seven million kroner (nearly £400,000) for this purpose.

The known iron-ore deposits of importance are four in number—Gellivare, Kirunavara, Luossavara, and Svappavara; of which the latter is of little immediate interest, as it is far from the projected line of railway. The standard description of these deposits is that of the special commission sent by the Swedish Government to examine them in 1875, and published by the Swedish Geological Survey in 1877.

Gellivare is in the extreme north of Sweden, 207 kilometres north-north-west of Luleä, on the Gulf of Bothnia. The ore-deposits occur in an irregular line of low hills, 4 or 5 kilometres in length, rising from the surrounding marshy land and forest, the ore being traced by its actual outcrop where the rock is bare, and by magnetic survey where the surface is covered with soil and gravel. The country-rock is gneiss, in which ore-layers of various size occur, and which includes dykes and masses of granite. The ore and gneiss are interbedded, and in places are curved and contorted together; the strike varies, but generally approaches north-east, with a south-easterly dip. The ore is principally magnetite, with a varying admixture of red hæmatite.

Of 41 general average samples taken by the Commission, 26 had over 70 per cent. of metallic iron; 13 gave from 60 to 70 per cent, and only 2 gave under 60 per cent. It is free from visible pyrites—9 only of the samples giving over 0·05 per cent. of sulphur, while 12 had none at all; but in places it shows considerable amounts of apatite sprinkled throughout the mass. Of the 41 samples taken, 10 showed less than 0·05 per cent. of phosphorus, 3 between 0·05 per cent. and 0·1 per cent., and 21 over 0·1 per cent., the highest being 0·7 per cent.; and it appears that the ore from the same mass contains largely varying amounts of phosphorus, which is confirmed by the experience of the charcoal-iron smelters, who have taken ore from here on a very small scale for over 100 years.

It will be seen that the Gellivare deposit is not, as before reported, a whole mountain of iron ore; it is only a mountain containing ore-belts and masses; but these are of great size, up to and over 100 feet in width, and include 5 per cent. of the surface over which they occur. The total area of the ore-masses is reckoned at 652,310 square metres (over 160 acres), or more than that of all the other deposits of Lapland put together; of this, 94,673 square metres is considered to be free from harmful impurities, and in belts of sufficient width. At 5 tons to the cubic metre, this should produce 473,365 tons of good ore for each metre sunk, or nearly seven times as much if the inferior ore is included.

The Kirunavara deposit is 312 kilometres from Luleä, in the same north-north-westerly direction, and is only 182 kilometres from the western coast of Norway, at Ofoten. There is here a hill over 3 kilometres long, running almost north and south, the mid ridge of which consists of solid iron ore, from 55 to over 230 metres wide, standing out in bold crests.

This deposit was known as early as 1736. The rock is greyish or reddish porphyritic *hälleflinta*, and the ore-mass, consisting exclusively of magnetite, is nearly vertical. Of 28 general samples taken by the Commission, 12 contained from 70 to 73½ per cent. of iron; 13 from 65 to 70 per cent.; and only 3 were poorer; the lowest result being 61½ per cent. The amount of sulphur is small, varying from 0·03 to 0·15 per cent., but the phosphorus is in places considerable. Only 4 samples gave from 0·03 to 0·047 per cent., the other 24 ranging from 0·305 to 2·802 per cent., with an average of 1·396 per cent. It is remarkable that all the samples from the middle of the deposit gave the highest results for phosphorus, while those taken farther north or south, towards either end, were progressively poorer, until ore of excellent quality, practically free from phosphorus, is reached.

As this deposit crops out at the surface along its whole length, and is free from detrital covering, its extent cannot be doubted. Its area is calculated at 311,000 square metres, the length being 4,157 metres, and the average width about 75 metres; at 5 tons to the cubic metre this would produce 1,555,000 tons for each metre in depth removed; and it is estimated that the enormous amount of 260,675,000 tons exists in the hill above water-level, available by open quarrying.

The Luossavara deposit is only 2 kilometres north of that just described, on the other side of a small lake, and in almost the same line of strike. The deposit here is in a conical hill, much covered with detrital matter and trees; the ore only crops out at the surface as a large mass at the top of the hill, its extent having been defined by compass surveys. These show its length to be 1,336 metres, and the breadth at the top is 46 metres, the area being taken at 49,276 square metres. This would give 246, 380 tons of ore for each metre of deposit removed, and it is estimated that 27,679,700 tons exist in the hill above water-level.

Of 8 general samples, 5 gave from 70 to 73 per cent. of iron, and 3 between 67½ and 69 per cent; the sulphur varying from 0·03 to 0·09 per cent.. For phosphorus, 2 gave under 0·01 per cent., and 4 others under 0·03 per cent., the remaining 2 giving 0·057 and 0·082 per cent.

Svappavara is about 60 kilometres north-east of Gellivare. Its iron-ore deposits are extensive, being 623 metres long by 53 to 98 metres broad, or an area of 37,376 square metres, so that each metre in depth should yield over 180,000 tons of ore, and it is estimated that between 66 and 67 million tons are available above the water-level. The ore is magnetite with hæmatite, containing from 50 to 73 per cent. of iron; sulphur is absent, but the ore contains from 0·129 to 1·547 per cent. of phosphorus. The deposit, being far from the projected line of railway, is now of little interest.

Prof. Helland next discusses the present sources of iron ore in Europe, and concludes that they are rapidly becoming inadequate to meet the demand, and that the British ironmasters in particular are likely to need large amounts of rich ore from new sources. He considers that they can best be supplied from these deposits, and that an output of some millions of tons per annum could not be considered as over-production. He then discusses the present condition of the projected railway from Ofoten on the Atlantic side to Luleä on the Gulf of Bothnia, which would open up the deposits, and shows that much work has been done on it already, and that the section from Gellivare to Luleä will probably be completed by the Swedish Government. The paper, which is accompanied by two good maps, is to be continued with a consideration of the cost of extracting the ore and of shipping it to foreign ports.

A. L. C.

ON THE FORMATION OF THE MOST IMPORTANT GROUPS OF IRON-ORE DEPOSITS IN SCANDINAVIA.

Om dannelsen af de vigtigste i Norge og Sverige representerede grupper af Jernmalmforekomster. *By* J. H. L. VOGT. *Geologiska Föreningens i Stockholm Förhandlingar, vol. xiv., pages* 211-248.

This number contains an exhaustive examination and classification of the iron-ore deposits of Norway and Sweden, from a theoretical standpoint. It ends with a complete summary of the whole paper in German. A. L. C.

THE IRON DEPOSITS OF EASTERN SPAIN.

Sobre los Criaderos de Hierro y de Plomo del Levante de España. *By* JUAN PIÉ Y ALLUÉ. *Revista Minera, vol. xliii., pages* 193-196 *and* 213-217.

The author deals only with the more commercially important iron deposits which are interstratified in the limestones, either contained entirely by them or at the contact with the slates. These deposits are of recent origin, contemporaneous with the present outline of the mountain-systems, and owe their origin to the thermal springs carrying iron in solution.

At the contact of the iron with the limestone or dolomite, and even separating the various kinds of ore in a deposit, it is common to find clayey bands analogous in chemical composition to the flucans of lodes; these doubtless result from the double decomposition in the limestone and dolomite and from the wear of the slates. The frequent presence of gypsum in the walls of the deposit is also easily explained by the action of sulphur-bearing waters on the limestones.

The following laws are found to obtain with reference to these deposits:—Their direction is always parallel to that of the range to which they belong; the dip is the same as the slope of the mountain; and the degree of inclination usually diminishes with increased distance from the summit.

Details of many of the more important outcrops in the Sierras Alhamilla, de Bédar, and de Enmedio, and the district of Morata are given in the paper, but are not here abstracted.

Without being equal to the best Bilbao ores, those of this region are suitable for all metallurgical operations. The sulphur and phosphorus are, with the exception of one district, below the limit allowed for first-class irons. The insoluble residue varies greatly, in some cases rendering careful washing necessary, whilst in others it is very low. The silica depends somewhat on the enclosing strata, the deposits enclosed in the Triassic ranges having less than those in the older rocks. The quantity of manganese is greater than at Bilbao.

The iron percentage, as would be supposed from the formation, is also variable. Where the metalliferous springs met with pre-existing cavities, the ore is of high quality; whereas where the limestone had to be dissolved away it falls into two classes of 47 per cent. and over 50 per cent. respectively. It is observed that where the deposits are largest the quality is best.

The essential difference between these deposits and those of Bilbao lies rather in their disposition than in their nature. Whereas at Bilbao we have a bed of great persistence, more or less horizontal, but of limited thickness, in Eastern Spain we have successive beds of less persistence, with approximately vertical inclination.

As to the quantities available, it is not possible to form any definite idea, but the region seems fitted to become the successor to Bilbao. The author mentions

estimates which have been made by various persons of the quantities available in different districts, amounting altogether to over 30,000,000 tons, and considers that these figures understate the case.

In subsequent numbers the geological conditions of the district are discussed at great length. G. E. C.

IRON-ORES OF SALEM, INDIA.

Preliminary Report on the Iron-Ores and Iron Industries of the Salem District. By THOMAS H. HOLLAND. *Records of the Geological Survey of India, vol. xxv., pages* 135-159.

Salem appears to be an important iron district. The chief ore is magnetite, which also contains the largest percentage of iron. A practically inexhaustible supply of ore, containing nearly 60 per cent. of metallic iron, is obtainable in the Salem district. The iron is very free from phosphorus and sulphur, although detailed analyses are wanting. Hæmatite is subordinate in importance. Ores formed by the weathering of hæmatite—limonite, brown hæmatite, clay-ironstone, etc.—occur, but, although used by the natives on account of their softness, they are of little importance. Chromite also occurs.

No manganese ores are known in the district. Corundum deposits, valuable possibly as a source of aluminium, occur.

These iron-ores are worked in a primitive and wasteful fashion by the natives, who make both wrought-iron and steel. Their methods are described as imperfect forms of the Catalan and bloomery processes of Europe and of America. The fuel used is charcoal, the harder and more slowly-growing native woods being preferred for this purpose.

Many thousand acres of available forest occur in the neighbourhood.

The following estimation of the timber supply per annum and the resulting yield of iron is given :—

	Timber. Tons.	Iron. Tons.
Salem talûq	5,736	400
Attûr „	833	58
Námakal „	5,366	416
Uttankarai „	8,140	625
Total	20,075	1,499

Investigation is required as to which of the native woods are the most suitable for the production of charcoal for iron smelting. G. W. B.

GOLD AND IRON-ORE IN ELDSLAND, TIERRA DEL FUEGO, ARGENTINE REPUBLIC.

Om recenta lager af jernmalm under bildning på Eldslandet. By ANT. SJÖGREN *and* C. JUL. CARLSSON. *Geologiska Föreningens i Stockholm Förhandlingar. vol. xiv., pages* 75-86, *and woodcuts.*

Mr. C. J. Carlsson was chief of an expedition sent in the latter half of 1886 to investigate part of Patagonia and Tierra del Fuego, which had been reported rich in gold. The expedition went from Punta Arenas, near the Magellanes Strait, by sea to Bahia Porvenir, on the north-west coast of Tierra del Fuego; thence it proceeded by Bahia Inutil to Bahia San Sebastian, on the east coast, from which, as a base, all the coast to lat. 53° 47′ south was investigated.

The rocks of the northern part of Tierra del Fuego are sandstones and conglomerates of Tertiary age, with occasional bands of lignite; and are thinly overlain by more recent (Quaternary) deposits. The Tertiary strata probably overlie schists of Cambrian age, as at Mendoza and other places in the Cordillera.

Gold is found in many places, on the sea-coast and in the beds of most of the rivers and streams coming down from the Cordillera, along the whole coast up to Santa Cruz in Patagonia, but seldom in paying quantities. The original source of the gold is as yet uncertain; but gold has been found in certain beds of the Tertiary strata, although in minute quantities only.

The gold is accompanied by magnetite and hæmatite, brownish-red garnet, dark hornblende, and titanite, forming a black ironsand, which is regarded as the best indication of gold. This ironsand is very common in the surface-deposits (Quaternary), especially on the seacoast and in some of the river-valleys, where it has been concentrated into considerable layers; as at Valle Cullan, where some Chilians have erected a dressing-works for its treatment; and at Nombre Head, where there is a layer about 1·20 metres thick, between the Tertiary and Quaternary deposits, only 4 or 5 metres from the surface. Similar sand is found along the whole line of the east coast, in a band from 0·01 metre to over 1 metre thick, and of varying width up to 10 or 15 metres, more or less mixed with quartz sand; and it is probable that similar beds exist at the sea-bottom for a considerable distance from the shore, as soundings often show black sand, and large amounts of it are cast up on the beach after strong easterly winds.

Gold sometimes occurs mixed with the sand; but it is more generally concentrated beneath it on the bed-rock, or in a cement of clay and small stones. Its appearance and composition (roughly, an alloy of 80 per cent. of gold, and 20 per cent. of silver) are the same over the whole district, except that in the interior the gold is generally coarser, nuggets weighing as much as 30 or 40 grammes having been found, while on the seacoast the largest hitherto found has not weighed quite 2 grammes. The deposits are extremely variable in value: one small layer gave 800 grammes of gold to the cubic metre of sand washed, but an average richness is about 15 grammes per cubic metre.

Mr. A. Sjögren suggests that the interbedded deposits of magnetite and hæmatite, so common in Sweden and North America, may have had an origin analagous to that of the beds of ironsand above described.

He thinks that an examination of the magnetite deposits, especially in their deeper workings, clearly shows them to have been formed contemporaneously with the enclosing quartzite, gneiss, or other strata, and that all the conditions would be met by supposing them to have been formed from the ferruginous detritus of older rocks, mechanically concentrated by running streams or by the waves of the sea.

A. L. C.

IRON-ORES OF MEXICO.

The Occurrence of Hæmatite and Martite Iron-Ores in Mexico. By ROBERT T. HILL. *American Journal of Science. Series iii., vol. xlv., pages* 111-119.

The paper refers to the descriptions by Mr. Birkinbine and Prof. Silliman of the famous Cerro de Mercado near Durango, and describes a similar deposit near Monclova, Coahnila, on the Mexican International Railway.

The mountain in which the deposit occurs is composed of nearly vertical strata of hard limestone of Lower Cretaceous age, traversed parallel to the stratification by vast masses of eruptive diorite, certainly of later origin.

The extensive talus of limestone *débris* around the base of the mountain is largely minged with rounded lumps of specular hæmatite. About 1,000 feet above the railway are exposed large masses of ore, in a line corresponding with the strike of the limestone-diorite contacts; resembling fragments of a vertical vein, but apparently non-continuous. Some are entirely in limestone, others entirely in

diorite, while several present a wall of each. They seem to have been formed by replacement of the limestone at the contact, or of the masses of limestone included in the diorite, and are certainly of later age than the enclosing rocks.

The ore has the external appearance of black magnetite, but the interior consists of bright specular hæmatite, studded with minute granules and octagonal crystals of martite.

In several outcrops about a foot of limonite is seen against the hanging-wall of limestone.

Many other similar deposits in Mexico are referred to, which in most cases seem to occur under the same geological conditions—folds of Cretaceous limestone, broken by diorite protrusions, and separated by valleys largely covered by the *débris* from the mountains.

The author is of opinion that these remarkable masses of hæmatite are likely to become an important factor in the future iron supply of the world.

G. E. C.

SAFETY NETS IN WINDING SHAFTS.

Sur le Filet de Sureté établi au puits Jules Chagot des Mines de Blanzy. By — LEBRETON. *Annales des Mines*, 1889, *series* 8, *vol. xv., pp.* 409-416, *and four figures.*

It sometimes happens that workmen fall into the shaft, either inadvertently or by a mistake in moving the cage. Sometimes the victim is killed, and at other times the injuries are slight, and it is possible to save him; if they are serious he may be drowned before it is possible to render him assistance.

At the Jules Chagot pit, a wire rope net has been placed about 2 yards below the keps at the lowest hanging-on, which is about 350 yards in depth.

The net, which hangs vertically when one side is released to allow the water tubs to pass, has meshes 4 inches square. It consists of galvanized steel wire ropes with a breaking strain of 21,000 lbs. per square inch of section. These ropes are formed of eighteen or twenty wires. The longitudinal ropes and the transverse ropes are bound together with galvanized wire to form the meshes. The net is formed with an edge formed of wire rope, with 133 wires about 1 inch diameter, and forms a rectangular net of 9 feet by 8 feet 8 inches. The net is suspended by bolts to two buntons placed below the hanging-on. Loops are formed on two opposite sides of the net, making the length of net, inclusive of loops, about 11 feet, and its weight about 290 lbs. The buntons to which it is suspended are 10 inches square and 12 feet 6 inches long. They are each fitted with five wrought-iron saddles, to which the loops of the net are attached by the wrought-iron bolts.

The cost of the net is from £20 to £25, and the cost of installation is about an equal amount.

This net has not been used in case of injury to workmen, but three accidents to material have taken place. Once the cage went too hard upon the keps, forced them back, and fell about 7 feet on to the net, which acted efficiently, and the damage was quickly repaired. Possibly in the absence of the net the rope would have been broken. On the second occasion, an empty tub and one of the cages, weighing about 6,600 lbs., fell into the net, from a height of 75 yards. Both tub and cage were comparatively uninjured, and the damage was cheaply repaired. On the third occasion, a full tub fell from bank, a distance of 350 yards, and the net was not seriously damaged.

M. W. B.

REPORT

OF THE

PRUSSIAN FIRE-DAMP COMMISSION.*

SECOND PART.—*Continued.*†

SCIENTIFIC AND TECHNICAL ENQUIRIES.

A.—Properties, Occurrence, and Ignition of Fire-damp.—*Continued.*

II.—Occurrence of Fire-damp in Mines.

1.—*General Considerations.*

62.—*Distribution of Fire-damp in the Prussian Coal-basins.*—As already mentioned (sec. 15), fire-damp is seldom met with in the Upper Silesian, Southern Harz, and the Ibbenbüren coal-fields. Although occasional fire-damp explosions have, during the last decade, occurred in Upper Silesian collieries, they were due not to natural mine gas, but always to local production of gas arising from fires in the collieries, and consequently to gases produced by such fires.‡

In the remaining six coal-basins of Prussia, fire-damp has been found for many years, and over a greater or less area.

In Lower Silesia, explosions were first noted in 1850, and since that time with the increasing depth of the mines they have become more frequent and extensive. The Abendröthe collieries near Kohlau, and the Rudolph collieries near Neurode, the seams of which have been subject to considerable faulting and other disturbances, are especially rich in gas.

In the small basin of Wettin and Löbejün in Saxony, fire-damp has been met with since 1846, but only in very small quantities.

The collieries working the North German Wealden coal-deposits, near Minden, have, by reason of the considerable production of fire-damp, comparatively early attained a sad notoriety. On August 19th, 1853, an explosion occurred in the Laura colliery, by which 11 men were killed, and up to that time this was the largest number of persons killed in any explosion in Prussia. The Wealden coal-mines in Hanover and near Obernkirchen (duchy of Schaumburg) have suffered less from explosions, although in deep workings in the latter district, gas is found in large quantities.

In the Lower Rhenish Westphalian coal-basin, so long as mining was restricted merely to the Ruhr district and in the upper seams, there were up to 1850 only a small number of fiery mines. But as mining operations extended to the east and north, below the more recent strata, which in this district cover the Coal-measures, and as mining was carried on at greater depths, the occurrence of fire-damp became

* Translated by Dr. P. Phillips Bedson up to sec. 70 inclusive, thence to the end by Mr. L. L. Belinfante. † *Trans. Fed. Inst.*, vol. iii., page 1105.

‡ Several instances are recorded in the *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxx., pages 354-355.

much more extensive and dangerous. At the present time, the greater number of the mines of this basin (representing 92 per cent. of the coal raised) are to be regarded as fiery—viz., all those yielding gas, flaming and bituminous coals, including those collieries working below the Chalk Marl.* According to the statistics of the local section of the Commission† at the commencement of 1883 of the 196 collieries in the Dortmund mining district there were 133 in which fire-damp had been observed, in 81 of these the evolution was continuous and regular, and in 52 it had been only occasionally found, in 4 of the 81 collieries the evolution of gas was especially strong, in 11 somewhat less marked, and in the remaining 66 it was comparatively weak. The most marked evolution of gas was found in 3 mines, the Neu Iserlohn, Bruchstrasse, and Mansfeld (Colonia shaft) collieries, near Langendreer, and also in the two pits of the adjacent Westfalia collieries, near Dortmund. As a general rule the middle and upper seams of the bituminous coal series are especially fiery.

In the Aachen coal-basin, the Wurm district, with zigzag folding of the coal strata, has yielded gas for ages, whereas gas has been but seldom met with in the more regular deposits of the Inde district (Eschweiler). It is noteworthy that in the Wurm district the long-flame coal and the anthracitic coal are equally rich in fire-damp. In the Saarbrück coal-field fire-damp has been met with for some years, and in 1820 in some of the mines special regulations were adopted in consequence. Since the working of the deeper seams, almost all the collieries have had to contend with gas. Those specially burdened are the mines working the strata of the lower series (bituminous coal) and those of the lower portion (semi-bituminous coal) of the middle series.

63.—*Other Modes of Occurrence of Fire-damp in Prussia.*—It may not be considered out of place to describe shortly the mode of occurrence of marsh gas or fire-damp in Prussia in other than coal-mines. As a rule gas is not met with in brown-coal or lignite-mines. Some time ago it was exceptionally observed in two mines in Silesia.‡ More recently (August 14th and 19th, 1880) two explosions of gas occurred in the lignite mines at Habichtswalde, near Cassel, where a lignite was worked much resembling ordinary coal, and the gas appears to have been produced under conditions very similar to those under which it is found in ordinary coal.§

In boring for petroleum in the oil-district near Peine (Oelheim) in the province of Hanover, discovered in the beginning of 1880, gas is met with of a nature similar to, and under conditions very like those obtaining in the oil-districts of Pennsylvania.

The occurrence of combustible gas in rock-salt deposits has been frequently observed. In the Gottesgabe salt-mine at Rheine (Westphalia) fire-damp has been found for many years, and has frequently been the cause of small explosions. In sinking shafts at the Stassfurt mines, gas has been met with since February, 1856, in the bitter and red salt (waste salt) deposits; so abundant is the evolution of this combustible gas, that to avoid danger it has been necessary to conduct it away in pipes;‖ and even in the more recent winnings, combustible gas has been frequently found in the upper salt-beds. In the neighbouring salt-mines at Westeregeln, a flame 5 feet long of these gases burnt from April to June, 1875, and

* *Appendices*, vol. ii., page 3. † *Ibid.*, pages 10-11.

‡ Dr. Serlo, *Treatise on Mining*, vol. ii., page 297.

§ In a brown coal-mine (pitch coal) at Falkenau in Bohemia, an explosion occurred in January, 1877 (*Oesterr. Zeitsch. f. Berg. u. Hüttenwesen*, vol. xxv., page 169). Fire-damp has also been met with in the Peissenberger pitch coal-mines in Upper Bavaria (*Zeitsch. d. Ver. Deutsch. Ing.*, vol. xxx., page 410).

‖ *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. v., page 240.

at Neu Stassfurt an almost equally long flame burnt from the end of December, 1878, to the close of February, 1879. The gas from the latter consisted of 93·1 per cent. of hydrogen, 0·8 per cent. of marsh gas, 5·8 per cent. of nitrogen, and 0·2 per cent. of carbon dioxide.* These gases differ from those usually met with in collieries by the larger proportion of hydrogen present in them.

The occurrence of fire-damp in the strontianite-mines in the Münster district, which has been frequently observed since December, 1881, is specially important for Westphalian coal-mines. Whether the gas met with in these mines in the marly clay in which the strontianite is found, is to be attributed to the coal strata below, or whether it has its origin in the more recent bituminous shales and specially in the asphalt met with in the marl, must still be regarded as an open question.

Finally, in respect to metalliferous mines, three considerable explosions are stated to have taken place in the Upper Harz in the years 1661, 1778, and 1829,† in each of these the gas in question was most probably marsh gas and sulphuretted hydrogen, produced by the decay of plants in stagnant water. In tapping the water, the gas rushing out with the water has been ignited by the naked lights, and thus not only have the miners been seriously burnt but also considerable damage has been done to the timbering of the mines.

2.—*Occurrence of Fire-damp in Coal and in the Surrounding Rock.*

64.—*In Coal.*—Marsh gas being one of the bye-products of the changes attending the gradual formation of coal from the decay of vegetable matter covered by mud and sand, is naturally formed in the coal-seams themselves, in which it must exist under greater or less pressure, filling all the fissures and pores of the coal, unless its position may have determined its passage into the surrounding rock or allowed of its free escape.

The enquiries of the several local sections of the Commission show that in Prussia the occurrence of marsh gas does not in any way appear to be related either to the kind of coal or the geological age of the seams. This conclusion is confirmed by the results of the investigations of Mr. E. von Meyer on the gases obtained from wrought coal (sec. 50). But little difference was found in the quantity of gas yielded by the bituminous and anthracite coals of the Wurm district (Aachen basin), both these coals yielding a considerable amount of gas. In the Saarbrück basin the largest amount of gas was obtained from the lower group of strata yielding gas coals; in the Lower Rhenish Westphalian basin from the middle group (bituminous coals) and again from the middle and upper seams; whilst in this basin the true gas and gas-flame coals yield but little gas, occasionally, as in the extensive workings of the Zollverein collieries, it is entirely absent. With respect to the gas contained in the coal in all the basins, the seams of one and the same group differ from one another, and even the same seam in its different parts may frequently show the greatest difference in this respect, so that it is not uncommon to find from neighbouring seams or workings the coal from one entirely free from gas, whilst from the other the coal is burdened with gas. A series of examples of this kind are given in the final reports of the local sections.‡ The occurrence of gas is affected much more by the conditions of stratification, the structure and nature of the surrounding rock, and that of the more recent rock coverings than by the nature of the coal itself or its geological age.

Where the lay of the seams is regular and they crop out at the surface a certain gradual evolution of gas has already taken place. How far such a liberation of gas

* Dr. Serlo, *loc. cit.* † Mr. Schell, "Mining in the Upper Harz," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxx., page 125. ‡ See section 9 of the Report, and *Appendices*, vol. ii., pages 10-11.

may have extended depends upon the dip of the coal-seams and upon the character of the coal, more especially its porosity and cleavage (sec. 49). In addition to the ordinary experience that with seams cropping to the day it is usual to find the coal near the outcrop practically free from gas, observations of an opposite character have not unfrequently been made, and in many seams which are entirely free from gas in the upper portions, considerable quantities of gas are met with at a depth of 325 to 650 feet. Folding of the strata and other irregularities of the deposits impede the natural outflow of the gas towards the outcrop, consequently the evolution of fire-damp is greater in the neighbourhood of anticlines, overthrusts and nips-out (and with coal of loose texture, or the occurrence of mineral charcoal), than with regularly lying seams, and is in fact more pronounced with anticlines than with synclines. Closed anticlines may become actual magazines of gas even at points quite near the surface. The mines of the Wurm district offer many examples of this kind, where, in some instances, in one and the same seam the limb of the anticline that crops out at the surface is found quite free from gas to the deepest point, whereas the closed anticline contains such considerable quantities of gas as to necessitate in a certain measure the tapping off of the gas by special drifts before the working of such district can be proceeded with.*

It is self-evident that the nature of the rock immediately surrounding the coal-seams, forming the roof and floor, must powerfully affect the amount of gas retained by the coal. A dense and non-porous or water-carry floor or roof tends to keep the gas in the seam, while porous, fissured, or dry strata facilitate the evolution of gas. Thus the seams with roofs of sandstone or conglomerate are generally found to be freer or poorer in gas than those covered with clay-slates. In the entire coal-mining district at Obernkirchen, the main seam is found to yield gas only when the roof, which is porous Wealden sandstone, is covered by Wealden clay-slate. Where this covering is wanting the gas has escaped, while the gas becomes more abundant with increasing thickness of the argillaceous strata. In the Wurm district, the sandstone roof, when it has been drained of its water for a lengthened period, takes up the greater portion of the gas, which on the crashing through of the sandstone may suddenly often invade the workings in considerable quantities. On the other hand, where the sandstone is still filled with water, the gas is retained by the coal, from which it can only be gradually evolved.†

The existence of covering of more recent rock-formations has similar effects in impeding the gradual evolution of the gas. This is the case even when, as for example, the porous Chalk Marl of the Lower Rhenish Westphalian basin, the rock takes up a considerable amount of gas from the coal-seams.

In conclusion, it appears that in all Prussian coal-fields, other conditions being the same, the evolution of gas increases with the increased depth, that is, with the greater thickness of rocks covering the coal. In individual cases, observations of a contradictory character have been made in collieries working under the marl in the Lower Rhenish Westphalian basin, more especially in the neighbourhood of Dortmund.‡

65.—*In the Surrounding Rock.*—In the majority of fiery mines the production of gas is not confined to coal alone, but extends also to the surrounding rock. This is chiefly the case with those porous sandstones (in immediate proximity to seams of coal) which have taken up a portion of the gas from the coal (sec. 64).

This gas will frequently make itself evident in working the coal. The majority

* *Appendices*, vol. i., pages 156-157; vol. ii., pages 12-13. "Ventilation of the Gemeinschaft colliery," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., pages 76-78. "Ventilation of the Maria colliery," *Ibid.*, page 87.

† *Appendices*, vol. i., pages 156-157 and 174-178. ‡ *Ibid.*, vol. i., page 111; vol. ii., page 12.

of the small blowers met with in making preliminary borings and sinkings are to be attributed to sandstones containing gas. The remarkable occurrence of gases in the water of the Kreuzgräben collieries (Saarbrück) is to be attributed to the same cause. The gas derived from the sandstone-rocks is contained in considerable quantities in the water, and is liberated on becoming heated in the condenser of the pumping-engine previous to being raised to the surface.

In addition to such secondary issues of gas, there are other cases known where the surrounding rock has given rise to the formation of gas. This is especially the case where the roof of the seam is a clay-slate with frequent bands of coaly substance scattered throughout (the so-called "burning shales"), from which fairly considerable quantities of gas are liberated during working. The clay-slate (Wealden shale) forming in all the mines at Obernkirchen the roof and floor of the main seam, is throughout rich in gas. In sinking a shaft in 1885 in this district, gas was met with as soon as the clay-slate, at a depth of 13 feet, was reached, and continued until the Wealden sand-stone was reached, at a depth of 551 feet (46 feet above the main seam). At a depth of 515 feet in a dark bituminous clay-slate containing many fossil shells and plants, the evolution of gas was so strong that the gases ignited by a shot were only extinguished at the end of 24 hours by filling up the shaft with stone.

3.—*Evolution of Fire-damp.*

66.—*Different Modes of Issue.*—The evolution of gas from coal or from adjacent rock, as a rule, takes place gradually and in small quantities, and is dependent upon the rate at which the seams of coal or stone are exposed in course of working. In some working places considerable volumes of gas are liberated in the form either of blowers, continuing for some time, or in the form of sudden outbursts.

In the majority of the fiery mines in Prussia, gradual evolution of gas is the rule, but this by no means excludes the possibility of the occurrence of blowers. Gas is usually given off uniformly from the whole of the exposed surface of the coal, whilst in the case of the adjacent rock it is usually liberated from the fissures and clefts. In virgin ground, and at the freshly worked face, more especially in moist seams, the peculiar crackling noise is observed, caused by the bursting of small water-bubbles filled with gas.*

The strength and continuance of the gradual evolution of gas is dependent, not only upon the initial pressure of the gas, but also upon the structure of the coal, that is, on the frictional resistance of the latter impeding the passage of the gases. Just as in the drainage of rocks, the absolute height of water-level decreases with the increased distance from the point of flow, more rapidly or slowly according to the permeability of the strata, so also the initial pressure of the gas in the coal may be gradually reduced in proportion to the area of the exposed surface of coal. A longer or shorter time is required to obtain equilibrium† of the pressure, and to produce a cessation of the evolution of the gas from the surface of the coal. In the majority of seams, the freshly exposed surfaces appear to give off the greater portion of their gas in a few hours, after which only a slight liberation of gas takes place, and this completely ceases in the course of a few months; in other seams the complete liberation of the gas often requires many years. An example of this kind

* Mr. Haton de la Goupillière (*Report of the French Fire-damp Commission*) attributes it to the splitting off of particles of coal brought about by the pressure of the gas endeavouring to force its way out through the pores of the coal.

† Mr. E. Mallard, "Remarks on Mr. Lindsay Wood's Experiments showing the Pressure of Gas in the Solid Coal," *Trans. N. E. Inst.*, vol. xxxii., page 123; and Mr. John Mayer, "On the Influence of the Atmospheric Pressure Variations on the Evolution of Fire-damp." *Oesterr. Zeitsch. f. Berg- u. Hutten-Wesen*, vol. xxxiv., pages 35, 53, and 69.

was observed in working the Grosslangenberg seam in the Wurm district, where, in working at a point only some 60 feet distant from a place which had been worked forty years before, the coal was still found to give off gas.*

Experiments made by Mr. Hilbck at the Westfalia pit showed that with hard coals more gas was given off from the broken masses of coal than from the solid blocks.† The hewn coal in the Neu-Iserlohn colliery also gave off perceptible quantities of gas when turned over at the face.‡ The investigations of Mr. E. von Meyer (sec. 49) and the practical use of coal show that certain varieties of coal retain a large proportion of their gaseous contents for a still longer time.

Blowers are met with in all coal-basins, but more frequently in the surrounding rock than in the coal itself. They are more frequent in cases where solid, fissured and water-free sandstone or conglomerate forms the roof or floor of a gassy seam, or where a new district of the mine is won from above, or when such a sandstone is cut through by a fault, and this is first driven into at a point in an otherwise undisturbed field.§ In such cases it is, as a rule, a question of tapping, at the first, of a greater or lesser quantity of gas, which has been gradually pressed from the coal-seam into the surrounding rock, in which the fissures and clefts have acted, to a certain extent, as reservoirs.

The gas rushes from the narrow fissures as a rule under great pressure with a hissing noise (hence the name "blower"), and is frequently mixed with water. The pressure of the gas frequently amounts to several atmospheres, and is naturally greatest when the blower is first struck. In boring in the Schaumburg mining district in the neighbourhood of Lindhorst on August 20th, 1869, at a depth of 695 feet, and in the Wealden slates (the main coal-seam being still 280 feet below), a blower was struck which sent up a column of gas and water to a height of 2 feet above the mouth of the hole, this lasted for an hour-and-a-half, and was frequently repeated at intervals until November 3rd of the same year.||

Exact measurements of the volume of gas yielded by such blowers are to hand only in the case of the blower in the König colliery, the gas from which was employed in the coal-dust experiments at Neunkirchen. This blower yielded 0·883 cubic feet per minute.¶ Dr. Schondorff has indirectly estimated that the blower met with in August, 1884, in the Shamrock colliery (Westphalia) gave 15·08 cubic feet of marsh gas per minute.** In former years, several blowers have been met with in Saarbrück collieries (*e.g.*, Albert colliery, which burnt with flames as thick as a man's arm and more than 3 feet long). A blower piped to bank at the Wallsend colliery (England) yielded, according to Sir F. Abel,†† 120 cubic feet per minute, and at another of the collieries on the Tyne a blower has produced from 6,000 to 7,500 cubic feet per minute.‡‡ Compared with the volume of gas issuing from the American petroleum wells, these volumes are extremely small—for instance, it is stated that one of the wells in the Murraysville district of the Pittsburg oil region yielded 30,000,000 cubic feet of gas in 24 hours.§§

Blowers differ considerably in the length of time they continue active; as a rule they are exhausted in a few months, still there are many instances in different coal-fields of Prussia of blowers retaining their activity for many years.

The accidental boring into a blower or the liberation of one by blasting offers special dangers, and, as a matter of fact, many of the great fire-damp explosions

* "Ventilation of the Gemeinschaft colliery," page 78. † *Appendices*, vol i., page 111.

‡ "Working and Ventilating the Neu-Iserlohn colliery," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 156. § *Appendices*, vol. i., page 155. || "Ventilation of the Schaumburg collieries," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 147.

¶ *Appendices*, vol. iv., page 13. ** *Ibid.*, vol. i., pages 37-38. †† Sir Fred. Abel, *Address of* November 18th, 1885, page 8. ‡‡ *Report of the French Fire-damp Commission* page 33.

§§ Sir Fred. Abel, *loc. cit.*

have been attributed to such accidents (sec. 26). As a rule, when the quantity of gas produced by a blower is considerable, it is rendered inoffensive by stopping up the hole and leading the gas away in pipes either into the return airways, under the furnaces, or it may be utilized for lighting up the shaft-bottom. A practice little to be commended, which at one time was much in vogue, was to ignite the gas in the mine and allow it to burn away; in such case there was a danger, either by abatement of the pressure of the gas or by some external cause—*e.g.*, the disturbance of the air by a shot, that the flame might be extinguished and thus give rise to considerable accumulations of gas in places which one might expect to be entirely free from gas.

No such sudden outbursts of gas have hitherto been known in the Prussian coal-basins as those which have so frequently occurred during the last decade in the Belgian and English coal-fields, and which have been the cause of some of the most serious explosions. These outbursts have been caused by the accidental piercing of a natural cavity in the coal in which many thousands of cubic feet of gas have been imprisoned under considerable pressure, or it may be that this sudden release has been caused by a falling in of the roof.*

On the other hand in some few mines a temporary, very marked, and even sudden increase in the proportion of gas evolved has been observed. These are usually at all events attributed to the piercing of a cleft or cavity in the coal. Instances of this kind have been observed at the Friedenshoffnung colliery (Lower Silesia),† and also at the Neu-Iserlohn colliery (Westphalia).‡

67.—*Influence of the Method of Winning and Working on the Liberation of Fire-damp.*—It is natural from the mode of occurrence of the gas that the first exploration of gassy seams—at any rate, below such depths as those at which the natural freeing of the gas at the outcrop is excluded—brings with it relatively the strongest evolution of gas. Freshly explored portions of the field and winning places are consequently the more dangerous, more especially if the seams in the upper strata have not been worked, and thus partially freed from gas. Generally speaking, in all fiery mines, it is the opening and fore-winning of deep workings which especially occasions fire-damp explosions.

The evolution of gas decreases more or less rapidly with the further advance of the fore-winning places, whilst in the ordinary working afterwards the gas evolution is on the whole still considerable (from the year 1861-1884 in Prussia, on an average, 34·1 per cent. of the fire-damp explosions occurred during the working, as against 64·2 per cent. during the driving of winning places, sec. 25), but in some cases the issue of gas sinks almost to zero. In the Schaumburg collieries the liberation of gas from the coal is almost at an end by the time the fore-winning is completed, and during the working, an ignition of fire-damp need no longer be feared, so that the working places may be safely supplied with small volumes of air for ventilation.§

* Mr. A. de Vaux. "Instantaneous Outbursts of Gas in the Workings of Collieries," *Ann. des Travaux publics de Belgique*, vol. xxiii., page 15. Mr. G. Arnould, "The Occurrence of sudden Outbursts of Fire-damp in the Collieries of Belgium," *Ann. des Travaux publics de Belgique*, vol. xxxvii., page 1. Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, pages 25-29 and pages 18-19. Prof. Kreischer, "Preliminary Report of the British Royal Commission appointed to inquire into Accidents in Mines," from the *Jahrb. f. Berg-, u. Hüttenwesen im Kgr. Sachsen*, 1882, pages 13-14 and 28-30. Sir F. Abel, *loc. cit.*, pages 14-15.

† Ventilation of the Friedenshoffnung colliery," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate* vol. xxxi., page 138.

‡ *Appendices*, vol. ii., pages 10-11. "Working and Ventilating the Neu-Iserlohn colliery," *loc. cit.*, pages 154 and 156-157.

§ "Ventilation of the Schaumburg collieries," *loc. cit.*, page 148. In No. III. shaft the above-named favourable conditions did not occur.

On the other hand, in the Wurm district the liberation of the gas continues for a lengthened period, in some cases for years, whilst in some seams even in this district after a few years the evolution of gas is no longer perceived.* In the Lower Rhenish Westphalian basin Mr. Hilbck found that the uncovered face of the coal is, in a month's time, so free from gas that it then only gives off very small quantities.† For this district it may be generally concluded that danger from fire-damp is by no means so great in pillar working as in the winnings. The accident statistics for this district fully bear out this conclusion, for according to these, 24·67 per cent. of the accidents occurring from 1861-1882 happened during the second working, and 71·98 per cent. during the fore-winning.‡ The rate of evolution of gas is doubtless determined mainly by the local conditions, more especially the thickness and position of the seam, the compactness and structure of the coal, the direction and frequency of the fissures and cleavages, and the structure of the surrounding rock. At the same time the mode and manner of exploring, of fore-winning, and of working will have some influence; at any rate these may materially affect the rate of gas evolution, and in this way the safety of working.

Further, it is clear that the freeing from gas of a new district of workings will be considerably accelerated, by a regular formation of levels from above downwards at points not too far apart, combined with a regularly planned working of exploring drift-ways, and, if possible, starting simultaneously from several points. The saddle-ways (into closed anticlines) in the Wurm districts must be regarded as exploring drift-ways, which, considering the conditions of stratification in that district, are driven some time before the actual working commences.§

By the fore-winning following or in part accompanying the exploring work, the rate of liberation of the gas from the coal is considerably accelerated. The results of a series of observations made on behalf of the Commission by Mr. Hilbck at the Westfalia mine show that in working a seam which does not give off its gas too slowly, the quantities of gas produced in the several sections, leaving out of consideration fissures or blowers, are proportional to the area of the freshly exposed surface of coal. These results confirm the generally accepted opinion based upon experience in mines in almost all coal-fields. The removal of gas from a new district will under like conditions be the more rapid, the more it is divided up by a large number of working-places, *i.e.*, the smaller the sections into which the district is divided.

For similar reasons, the mode of winning affects also the removal of gas. In long-wall, as also in stoping or in working by banks, one has continually to work with freshly exposed surfaces, and therefore in gassy seams from the working faces, there is the greatest possible gas evolution active during almost the whole operation of winning, whereas in pillar work the greater proportion of the coal (in the pillars) is won after the greater amount of the gas has been liberated.

68.—*Quantity of Gas given off by Coal.*—The first investigations on the amount of gas given off by coal when worked were conducted by Dr. Schondorff,‖ during the years 1873-1876. In this enquiry Dr. Schondorff determined by anemometric measurements and chemical analysis of the return airs in many of the Saarbrück collieries, the deterioration of the air in its passage through the mine, as

* "Ventilation of the Gemeinschaft colliery," *loc. cit.*, page 78.

† *Appendices*, vol. i., page 108; vol. iv., page 113. ‡ *Appendices*, vol. ii., page 7.

§ "Ventilation of the Gemeinschaft colliery," *loc. cit.*, page 78.

‖ Dr. Schondorff, "Examination of the Return Air-currents of the Saar collieries," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxiv., pages 75-125.

represented by the loss of oxygen, and the increase of carbon dioxide and of marsh gas. The following table represents the results of certain observations relating to the marsh gas contained in air-currents:—

No.	Name of Colliery and Air-current.	Volume of Air per Minute.	Per Cent. of Marsh Gas.	Total Volume of Marsh Gas per 24 hours.
	Middle Zone.	Cubic Ft.		Cubic Ft.
1	Albert colliery, east district ...	17,000	1·389	340,100
2	„ west „ ...	15,610	0·648	145,700
3	Von der Heydt, Amelung seam	34,550	0·179	89,060
4	„ Beust seam ...	14,750	0·359	76,120
	Lower Zone.			
5	Salzbach	18,680	0·145	38,980
6	Altenwald, Nos. 5 and 6 levels...	21,920	0·165	52,080
7	„ Nos. 1, 2, and 3 levels	37,080	0·116	61,980
8	„ No. 4 level	13,040	0·303	56,920
9	Heinitz	27,990	0·247	99,760

In 1882-1884, Dr. Schondorff,* at the request of the Commission, extended this investigation to mines in other districts. The proportion of marsh gas found in the main air-currents was found to be within the following limits:—

In the Lower Rhenish Westphalian basin from 0·002 per cent. (Ruhr and Rhine) to 1·428 per cent. (Neu-Iserlohn II.)

In the Saarbrück basin from 0·053 per cent. (Reden) to 1·463 per cent. (Dudweiler, seams 5 and 6).

In the Aachen (Wurm) basin from 0·65 per cent. (Maria) to 1·564 per cent. (Maria II.)

In the Lower Silesian basin from 0·275 per cent. (Glückhilf, Wrangel pit) to 0·918 per cent. (Friedenshoffnung).

The following table gives the total volume of gas in 24 hours found in the return airways in some of the most fiery mines, the samples being taken on the occasion of the visits of the local committees.

	Cubic Feet.
Neu-Iserlohn, No. II. shaft (Lower Rhenish Westphalia)	897,600
„ No. I. shaft „ ...	305,000
Westfalia, Kaiserstuhl shaft „ ...	583,700
Albert shaft (Saarbrück)	330,000
Goulcy-Gemeinschaft-Königsgrube (Aachen) ... about	295,000
Friedenshoffnung, southern section (Lower Silesia) ...	256,500
Schaumburger, No. III. shaft (Wealden) ... ... about	280,000

In respect to the question as to the amount of gas exuded in relation to the surface of coal exposed, especially interesting information is to be found in the report on the Gemeinschaft colliery.† In this particular colliery, the Grosslangen-

* Dr. Schondorff "Chemical Investigation of the Fire-damp in Prussian Mines," *Zeitch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., pages 435-445, and vol. xxxii., pages 509-519. Prof. Winkler, in 1881, conducted a series of similar examinations of the air of the mines in Saxony. The results of this investigation were published in the *Jahrb. f. d. Berg-, u. Hüttenwesen im Kgr. Sachsen*, 1882, pages 65-84.

† "Ventilation of the Gemeinschaft colliery," *loc. cit.*, pages 77-78.

berg seam, which is most extensively worked, yields gas in all the districts. In that portion which yields an anthracite coal the gas comes off more from the sandstone roof than from the coal itself, and here the evolution of gas may last for ten years, because, as a rule, it commences first with a fall of the roof. In that portion of the seam which yields a flame-coal (east of a large fault) the gas is almost exclusively contained in the coal, and the exudation is usually completed in the course of three years. In 1882, 200,000 cubic feet of gas were given off daily from the anthracitic area of the Grosslangenberg seam, whilst the flame-coal area yielded 130,000 cubic feet daily. The coal worked in the anthracitic sections of this seam during the last ten years would correspond to an exposure of a surface of 3,300,000 square feet; therefore, for every 1,000 square feet of surface, there would be an evolution of 60 cubic feet of gas per diem, and since the evolution has lasted ten years the total volume of gas would at the least be $10 \times 365 \times 60 = 219{,}000$ cubic feet. Taking the entire thickness of the coal and sandstone from which the gas exudes as 40 feet, then every cubic foot of rock must have contained 6 cubic feet of gas enclosed in it. In the flame-coal district, reckoning the area of the exposed surface at 2,109,000 square feet (representing only those seams which have been worked during the last three years, to which the gas exudation must be regarded as restricted) the thickness of rock holding gas may be taken at 4¾ feet, taking the exudation at 60 cubic feet for every 1,000 square feet of area, the total volume of gas liberated from the entire mass would be 65,700 cubic feet, *i.e.*, 13·8, cubic feet of gas per cubic foot of coal. Consequently, in the flame-coal district the gas must have had an average pressure of 13·8 atmospheres.

In October, 1882, Mr. Hilbck* investigated in a fiery seam of the Kaiserstuhl shaft of the Westfalia colliery, near Dortmund, which at the time embraced a surface area of 110,000 square feet. This investigation showed that every cubic foot of solid coal in the kirved portion of the seam produced 9·7 cubic feet of gas, 875 cubic feet of gas from every ton of coal worked, and 81 cubic feet of gas from every square foot of coal surface exposed. On the other hand, it was shown, on January 30th, 1884, in the old Westfalia shaft of the same colliery, in the southern portion of this field, that for every ton of coal raised daily only 54 cubic feet of gas was given off, and in the region of the northern main airway 60 cubic feet of gas. On the other hand, in one of the branch airways, in a portion of the seam only recently worked, 824 cubic feet of gas were produced for every ton of coal raised, and 236 cubic feet of gas for every square foot of freshly exposed coal.

The experiments made by Mr. Hilbck, Commissioner, from November, 1884, to August, 1885, on behalf of the Commission, on the gradual exudation of gas from the workings of the Kaiserstuhl shaft† show, although circumstances interfered with their completion, in what way, in seams which are rapidly freed from gas, the gas is evolved in the individual sections of pillar working. The district of the seam in question was 492 feet long, 256 feet wide on the inclination of the seam, and 125,952 square feet of surface, with a coal content of 20,000 tons (6½ feet being the thickness of the seam, inclusive of 12 inches of stone band, soft bituminous coal, and 65 to 75 degs. dip of the seam); this is divided up by a single-track haulage-way whence diverge seven roadways 6½ feet high and 6½ feet wide, with pillars 33 feet thick, these are again split by rise drifts and are worked backwards from the boundary of the district. After the completion of the haulage road in November, 1885, the average exudation of gas during the continuation of the working was as follows:—

* "On the Quantity of Gas exuded by the various Sections of the Seams of the Westfalia colliery." *Appendices*, vol. i., pages 106-111.

† *Appendices*, vol. iv., pages 113-124.

Months.	Per Ton of Coal Raised.	Per Square Foot of Surface Exposed.	Per Square Foot of Freshly Exposed Coal.
	Cubic Ft.	Cubic Ft.	Cubic Ft.
I.—Whole working.			
December, 1885 ...	657	46·9	105·7
January, 1886	880	33·8	110·6
February „	833	25·6	110·3
March „	876	23·9	109·3
II.—Passage from whole to working of pillars.			
April, 1886	1,165	18·0	152·6
May „	1,278	14·7	—
III.—Pillar working.			
June, 1886	749	—	—
July „	463	—	—
August „	438	—	—

For further information respecting these values, the Appendix, already referred to, must be consulted. It may, however, be mentioned that during the whole working 848 tons of coal were raised on an average during each month, and a surface of 6,200 square feet of coal was freshly exposed; and during the transition period the coal raised was 571 and 446 tons, representing 4,350 and 1,750 square feet of freshly exposed coal, making altogether 38,400 square feet of coal surface exposed. During the three months of pillar working, the coal production rose from 855 to 1,368 tons; the total amount of coal got from this portion of the workings during the period of the experiment, was 8,838 tons, which does not represent half the coal in the part of the mines concerned. The above experiments show conclusively that the exudation of gas became steadily smaller during the pillar working.

The amount of gas found in the air-currents on Sundays shows what an important part in the production of gas is played by the freshly exposed surface of newly-worked coal, and by the operations of working and breaking up of the coal. Dr. Schondorff* found, on Tuesday, September 20th, 1875, in the airways of the Heinitz colliery (Saarbrück), an hourly evolution of 4,157 cubic feet of marsh gas, and this with 727 men at work; whereas on the following Sunday, with the mine laid off, the amount of gas produced was only 2,446 cubic feet. Similar investigations of the air of the mines of Saxony have, with few exceptions, shown a considerable reduction in the proportion of marsh gas in the air on Sundays as against working days.†

4.—*Accumulations of Fire-damp in Old Workings.*

69.—Opinions as to the occurrence of fire-damp in the old workings are extremely varied. Whilst in many fiery mines its presence in the old workings is absolutely denied, in many other instances, especially in most of those mines in which there is a considerable evolution of gases, it has been found necessary either to completely shut off the old workings or to moderate the ventilating current, so as in this way to render as harmless as possible the fire-damp which accumulates in them.

There can be no doubt that a portion of the gas, liberated in the working of the coal, escapes the influence of the ventilating current and accumulates in cavities in the roof or passes directly into the old workings. The proportion of gas which so accumulates will be the greater, the slower the air-current at the working-places.

* "Examination of the Return Air-currents of the Saar Collieries," *loc. cit.*, page 108.

† Mr. Cl. Winkler, "Chemical Examination of the Return Air-currents in various Collieries in Saxony," *loc. cit.*, pages 82-83.

The gas which accumulates in the goaf in this way will constantly receive additions from that exuding from the standing pillars of coal and from fissures in the surrounding rock. Considerable volumes of gas may find their way into the working portions of the mine, especially from falling of the roof or by reason of its slow and gradual settling down. Consequently, to the method of working must be attributed a certain influence on the amount of gas accumulating in the goaf; it is evident that a method of working with a complete and carefully arranged system of stowing must reduce to a minimum such accumulations of gas, for it not only restricts the dimensions of those spaces which serve as gas reservoirs, but also prevents extensive and sudden fissuring of the roof.

On the other hand, the accumulation of gas in the goaf lasts, as a rule, only a short time; for experience shows that it is gradually given off again, and perhaps also in part undergoes decomposition. If then, in course of time, no renewal of gas takes place, the air in the goaf will be found gradually becoming poorer in marsh gas and richer in carbon dioxide. Only in this way can Dr. Schondorff's* statement be explained that the goaf adds less marsh gas than it does carbon dioxide to the air of a mine.

A sample of the air of the goaf, taken by Dr. Schondorff in the Shamrock pit at Herne (Westphalia), from an opening in a dam, with which seam No. 5 is walled off from the air-drift, was found to have the following composition :—

	Volume. Per Cent.
CO_2	7·535
CH_4	2·148
O + N	90·317
	100·000

This gas extinguished a safety-lamp held in front of the opening.

With respect to the gradual change in composition of the air in the goaf, diffusion (or rather the difficulty in effecting diffusion) plays no unimportant part. The considerable difference in specific gravities between marsh gas and carbon dioxide will naturally facilitate the accumulation of the former in the upper strata of the uneven spaces left in working and tend to favour the permanent maintenance of such accumulations in considerable quantities for many years, especially where no attempt is made to ventilate these portions of the mine.

As a matter of fact, numerous observations have been made in different coal-fields, both in Prussia and other countries, which show that old workings, at one time rich in gas, have been found on re-opening (or on holing) to contain no more marsh gas but simply stythe and carbon dioxide.† Still there are cases known which show that this disappearance of marsh gas may take a very considerable length of time. For instance in 1882, in the workings of the Oelsnitz Mining Company (Kingdom of Saxony) a large volume of gas‡ was met with in breaking into a portion of the mine which had been closed since 1874. Again, according to Mr. Nasse,§ even ten years after the completion of the working of a section of the Beust seam in the Gerhard colliery (near Saarbrück) varying amounts of marsh gas were from

* *Appendices*, vol. i., page 35.

† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, pages 43 and 44. Mr. Hoernecke, "On Precautionary Measures against Fire-damp, etc.," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 281.

‡ Mr. B. Otto, *Fire-damp and no Aim of Providence*, Berlin, 1886, page 6.

§ Mr. Nasse, "Observations on the Relationship between the Appearance of Fire-damp in Coal-mines and the Variations of Atmospheric Pressure," *Zeitsch. f. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxv., page 267, etc.

time to time observed behind a triple masonry dam shutting off this portion of the workings. At any rate, this much may be regarded as certain, namely, that the old workings of a coal-mine may (at least for some years following the winning of the coal) act as a storehouse of gas and consequently require the most careful attention.

How great a magnitude these spaces may assume in extensive mines, with incomplete stoppings, and consequently how enormous the quantity of gas which may have to be dealt with, is, for instance, seen from a calculation made by Mr. Hilt.* According to this calculation in the district traversed by a single air-current in the Ath-Goulcy colliery (Wurm coal-field) the space of the goaf, taking into consideration the breaks of the immediately neighbouring roof, as also the general composition of the superincumbent strata, was 9,110,000 cubic feet, and 7,410,000 cubic feet in the case of an air-current in the Gemeinschaft colliery. In English mines† still more extensive spaces have been found, in one case as much as 36,000,000 cubic feet. It is easily explicable that such extensive spaces must, as Mr. Hilt remarks, serve to make the goaf act as a regulator for the amount of gas contained in the return air; and in certain mines the variations in the evolution of gas caused by the exposure of fresh surfaces of coal, or by the temporary stoppages of work in the course of the day or week, may be in this way completely compensated.

The danger which such accumulations of gas in the goaf offer consists less in the possibility of ignition on the spot itself, although such cases have occurred, but rather in the possibility of more or less of this gas finding its way imperceptibly into the workings still in active use, and thus giving rise to explosions. Such a passage takes place slowly as a rule, and with a falling barometer, but may occur suddenly in consequence of violent aerial movements. Falls in the roof of the goaf have proved specially dangerous in this regard, leading to a sudden forcing out of air under strong pressure into the workings of the mine. A not inconsiderable number of the more extensive fire-damp explosions in English collieries have been attributed to this cause.

To prevent as far as possible these accumulations of gas in the goaf, the return air is, in many mines, led through it. This, however, does not completely obviate the danger, as the fissures and irregularities in the roof remain almost untouched by the air-current; nor is the ventilation of the goaf by any means advisable in seams where there is a tendency to spontaneous ignition. In such cases it is better to brick off the worked-out places at once, if only with a view to diminish as little as may be the ventilating current, and at the same time (to prevent gas tension in these closed spaces) an upward communication should be left in them with the return air-current. In the various Prussian coal-mining districts both systems obtain in practice to an equal extent.‡ The Commission have not been in a position to pronounce definitely in favour of one or the other of these methods (compare art. 14 of the "Principles").

5.—*Atmospheric Influences.*

70.—*Variations of Barometric Pressure.*—The relation between varying barometric pressure and the occurrence of fire-damp has been a subject of discussion and observation these many years past,§ despite which no very clear view of the case seems to have been arrived at. While, on the one hand, Messrs. Scott & Galloway,‖ basing their conclusions on a comparative synopsis of the fire-damp explosions that occurred

* *Appendices*, vol. iv., pages 110-111.

† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 42-43.

‡ *Appendices*, vol. i., pages 155-156, 177; vol. ii., pages 178-179.

§ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 40-52.

‖ *Proc. Roy. Soc.*, 1872, vol. xx., page 292; *Quart. Journ. Meteor. Soc.*, Oct., 1873 and Oct., 1874 (French translation in the *Annales des Mines*, 1877).

in England between the years 1868 and 1872, and of the contemporaneous meteorological observations, attribute the vast majority of these explosions to an alteration in the barometric pressure or in the temperature ; on the other hand, Mr. Le Chatelier* scouts the idea of atmospheric pressure having any such effect, and the French Fire-damp Commission, in their final report drawn up by the above-named engineer and Mr. Mallard† express themselves as follows :—"The hypothetical influence of a sudden drop in the atmospheric pressure, though theoretically possible, can rarely in practice make itself felt, and is really of small account."

In mining circles in England, as in Germany, it has now long been held for an undoubted fact that variations in atmospheric pressure do exercise some influence on the evolution of gas. Most practical men, forming their judgment from experience in the mine, incline to the view that a depression, and more especially a rapid depression of the barometer, is coincident with an increase in the volume of gases which stream into the pit workings. Consequently in nearly every mining district in both countries the custom of making regular barometer observations in fiery mines has gradually gained ground. Indeed the custom has become a mines regulation, a law, as for instance provided by the Coal-mines Regulation Act in England in 1872. The want, however, had made itself felt of sufficiently extensive and trustworthy experiments or observations which should enable one to grasp the question of the influence of atmospheric pressure in all its bearings.

Mr. Combes had already pointed out‡ that in making researches as to the influence of varying atmospheric pressures on the occurrence or accumulation of fire-damp (and it will be observed that this is all we have to deal with just now—not with the secondary question of possible explosions, which may arise at any time and from very dissimilar causes) we must first of all distinguish between the effect on gases which have already been evolved (whether they occur unmixed or, as actual fire-damp in such available spaces as the old workings afford) and the effect—favourable or unfavourable—on the issue of such gases as are still occluded in the solid coal or in fissures, etc., in the same.

The first-mentioned effect is at the present day almost universally recognized. Even Messrs. Mallard and Le Chatelier admit that it is "possible, if by no means proved as yet."§ As a matter of fact we are in possession of the results of practical experience in a great number of coal-mining districts, which all place beyond doubt the interdependence of a sinking barometer with abundant evolution of fire-damp from old workings. And this not only in pits with natural ventilation, but also in those provided with an artificial ventilation.‖ In the overwhelming majority of cases the evolution of fire-damp has been observed to occur more or less quickly after a fall of the barometer, but in some isolated cases it is said to have preceded this fall.¶

The assertion, on the other hand, that varying atmospheric pressure has any notable influence on the issue of gas from the solid coal-face has met with decided opposition, not only from Messrs. Mallard and Le Chatelier, but from many English and German experts. At the very least it is claimed that the effect is insignificant—

* "On the Influence of Variations in Atmospheric Pressure on the Evolution of Fire-damp." *Appendices to the Report of the French Fire-damp Commission*, vol. i., page 98, *et seq.*

† German translation, *op. jam cit.*, page 292.

‡ *Treatise on Working of Mines*, Paris, 1841, vol. ii., page 535.

§ *Final Report of the French Fire-damp Commission*, Germ. trans., *op. jam cit.*, page 292.

‖ Mr. Nasse, "Observations on the Relationship between the Appearance of Fire-damp in Coal-mines and the Variations of Atmospheric Pressure," *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxv., page 267, *et seq.*; Mr. Joh. Mayer, "On Mine Ventilation in the Ostrau-Karwin Coal Districts," *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1884, pages 154-155 (*Monograph on the Ostrau-Karwin Coal-field*, Teschen, 1885, pages 213-216); Mr. B. Otto, *Fire-damp*, etc., pages 10-17; Mr. Fr. Ritter von Rziha, *Fire-damp*, Vienna, 1896, page 54, *et seq.*

¶ Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *op. jam cit.*, page 290.

when one considers how small a proportion the greatest variations in atmospheric pressure bear to the generally considerable tension of gas in the standing coal.*

Recently a great advance has been made towards clearing up this point by the series of experiments carried out all but simultaneously at the Gabriel pit, near Karwin (Austrian Silesia), and at the Gemeinschaft and Ath-Gouley pits near Aix-la-Chapelle (Wurm coal-district).

The experiments conducted at the Gabriel pit, near Karwin, under the direction of Mining-Superintendent Chevalier von Walcher, during the months of June and July, 1885,† were temporarily confined to the comparison of the volume of gas (determined by anemometer measurements and chemical analyses of the pit air) with the variations in atmospheric pressure (indicated by a registering barometer below-ground). The only place where the air was at first sampled was the inlet of the ventilator—whereby account could be taken of the composition of all the air in the mine, inclusive of that proceeding from the goaf. Later on, as a second sampling-point, a deep level was selected which did not in any way communicate with old workings—so that here one would be mainly dealing with the gases issuing from the solid coal-face. In conjunction with these experiments a few experiments were made in which the pit air was artificially rarefied by shutting off the downcast air-shaft while still allowing the ventilator to go on working regularly. The published report of the results of these experiments as a whole summarizes as follows the general laws deduced from them :—

1.—The gaseous constituents [fire-damp] in pit-air generally diminish with a rising and increase with a falling barometer.

2.—The more steeply the atmospheric pressure-curve falls, the more rapidly does the gaseous content increase; and, inversely, the latter diminishes the more rapidly the more steeply the atmospheric pressure-curve rises.

3.—The evolution of fire-damp is not dependent upon the absolute fall of atmospheric pressure.

4.—If the atmospheric pressure-curve, after rising steeply, continues to rise at a more moderate angle; or if the atmospheric pressure, after having attained a maximum, remains for a considerable time at the same level, the gaseous content is observed to increase slowly. On the other hand, if after a sharp fall of the barometer, the latter continues to go down, but more slowly, or if the atmospheric pressure-curve, having reached a minimum remains for a considerable time at a low level, the gaseous content is observed to diminish slowly. Wherefore the maximum, or as the case may be, the minimum of the barometer-curve does not necessarily (or always) correspond to a minimum or a maximum of the gas-curve.

The experiments conducted on behalf of the Prussian Commission by our colleague, Commissioner Hilt, almost simultaneously with the Karwin experiments, during the months of September and October, 1885, at the Gemeinschaft and Ath-Gouley pits, near Aix-la-Chapelle,‡ have, in all essential points, confirmed the

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., page 42; Mr. Hoernecke, *op. supra cit.*, page 283; Prof Kreischer, "Preliminary Report of the British Royal Commission," *op. jam cit.*, page 14; Mr. Joh. Mayer, "On the Influence of Atmospheric Pressure Variations on the Evolution of Fire-damp," *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1885, Nos. 3-5.

† "On the Influence of Barometric Variations on the Evolution of Fire-damp. Report on the Experiments conducted with Reference to this Question in the Archduke Albert's Colliery at Karwin, Austrian Silesia," published by the Archducal Mining Authorities at Teschen, 1885; *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1885, page 668; *Zeitsch. des Vereines Deutscher Ing.*, 1885, page 893; Mr. E. Suess, "On Fire-damp," *Verhandl. der k. k. geologischen Reichsanstalt*, 1885, No. 13.

‡ Mr. Hilt, "Report on Experiments concerning the Influence of varying Atmospheric Pressure on the Evolution of Pit Gas," *Appendices*, vol. iv., pages 89-112; and *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., page 72, *et seq.*

results obtained at Karwin. But they are furthermore of particular value, inasmuch as they serve to show separately the influence of variations in atmospheric pressure on the gases accumulated in the old workings, on the one hand, and on the gases evolved from the fresh coal-surfaces on the other hand. Of the six series of experiments carried out in both pits, in the first four, two districts, in which were very extensive old goaves were dealt with; in the remaining two, a recently-opened dip working, and a longwall working, with stowing and well-ventilated, which had been in operation for eighteen months, were respectively dealt with. Barometer observations were made regularly four times a day aboveground, and the determination of the volume of pit gas evolved was made once daily in September and three times daily in October, by means of accurate anemometer-measurements and chemical analysis of the samples of air.

Although the variations of atmospheric pressure during the months of September and October, 1885, were comparatively insignificant, their influence is plainly discernible throughout the six series of experiments. A rise in the barometer is invariably followed by a diminution, a fall by an increase, in the proportion of fire-damp and carbon dioxide present in the return air—and this after an interval the length of which never exceeds 24 hours. The more rapid is the rise or fall in atmospheric pressure, the greater is the variation in the proportion of gases present. Moreover, a certain tendency was observed on the part of the marsh gas to approximate to a state of equilibrium independently of the atmospheric pressure, in such wise that when the volume of gas, by reason of a considerable fall in atmospheric pressure, has risen much above the mean, it appears to have a tendency to sink back again to the mean.

The experiments further demonstrate the enormous importance (in this question of the effect of atmospheric pressure) of the existence of extensive old workings. Thus, in the Ath-Gouley pit (where, as a matter of fact, the significance of this point had been recognized in practice for many years past), in a district with 9,110,000 cubic feet of goaf-space, there were observed between October 11th and 17th—with comparatively slight change in atmospheric pressure—actual variations of 70 per cent. in the mean volume of pit gas; while it was found impossible to determine any variations occasioned in the course of a single day by the operations of coal-winning, or by the stoppage of such operations (compare par. No. 69 of this Report). There is no doubt whatever that, taking into account the circumstances of the Ath-Gouley pit, a barometric fall of any considerable importance might easily be followed there by a rise of 100 (or more) per cent. in the proportion of gas present in the return air-current.

The experiments in the longwall and dip workings of the Gemeinschaft pit, where, in the main, one had only to deal with the gas evolved from the face of the solid coal, indicated a greatly diminished influence of the atmospheric pressure. And yet the effect of every rise and fall of the barometer was perceptible, if somewhat influenced by the (here plainly discernible) variations depending on the operations of coal-winning. That the observed effect was indeed chiefly traceable to gas evolution from the face of the coal, and not to possible accumulations in such empty spaces as drifts, interspaces in stowing, etc., might afford, was proved by Mr. Hilt's calculations. He shows that if one accepted the latter supposition (empty spaces), for a 31 hours' fall of barometer on October 21st and 22nd, reckoning from the increased proportion of gas present in the return air-current, the volume of gas in the hollow spaces (even if these had been exclusively filled with gas) would have had to increase by 5·3 per cent., whereas atmospheric pressure had only fallen by 0·8 per cent.

In full accord with the results of the Karwin experiments and those of Commis-

sioner Hilt, Dr. Broockmann* has shown that variations in atmospheric pressure have an undoubted influence even on the gas issuing from blowers. To prove this, during the months of November and December, 1885, and January, 1886, he compared the daily recorded flame-heights of the blower led into a tube and burnt (at the Hanover II. pit, near Wattenscheid, Westphalia), with the atmospheric pressure-curves obtained by means of a recording barometer.

Chief Engineer Joh. Mayer, who† has been long busied with exhaustive researches on gas evolution in the Kaiser Ferdinands-Nordbahn collieries at Polnisch-Ostrau, fully admits (as a result of his observations and experiments) the influence of barometric variations on the fire-damp present in old workings. Nor does he deny that such variations have some influence on the exudation of gas from the solid coal-face—but he regards this as unimportant, and certainly as insufficient to disturb the proper ventilation of a well-ordered mine. Mr. Mayer explains his views by means of the following considerations:—The gases are partly exuded from coal-surfaces previously laid bare—these continue gradually to get rid of their contained gas—partly (and that for the greater part) from the fresh-hewn surfaces, of coal in the actual process of coal-working. The second mode of issue of the gases can hardly be affected to any appreciable extent by atmospheric pressure, because it takes place too quickly—while fresh surfaces with gas at considerable pressure are being continually laid bare. There remains then only to be considered the gradual evolution of gas from the coal-faces previously laid bare. But, taken all in all, the influence of atmospheric pressure (upon this evolution) has no great bearing on the ventilation of a pit. Experience shows that the seams exhaust themselves of their contained gas in a comparatively short interval of time after the process of fore-winning; and therefore those coal-surfaces which could in any degree be affected by atmospheric pressure are very small indeed. For the rest, Mr. Mayer expresses himself very strongly (and, we think, with good reason) against the rather too far-reaching conclusions which have been drawn from the results of the Karwin experiments—particularly as to the connexion between extensive fire-damp explosions and barometric variations, and as to the prevention of fire-damp explosions.

The Prussian Commission, having already concluded their plenary deliberations in June, 1885, had no further opportunity of expressing their views with regard to the results of Commissioner Hilt's experiments and those of the experiments carried out at Karwin. But, dealing generally with the question, the Commission had previously (at their meeting of December 13th, 1884) assented to the proposition of the Dortmund Local Section‡ which says:—"It is advisable to make regular and careful barometer observations in all fiery mines, and to provisionally increase the ventilation when there is a low barometer and considerable variations of atmospheric pressure."

Although one must needs admit that a great many points in the whole question of the influence of variations of atmospheric pressure require further explanation—for practical purposes it will be completely sufficient to keep a careful and intelligent watch upon the barometric conditions of the mine in the manner above indicated by the Commission. To much the same opinion the overwhelming majority of experts in England appear to incline; and especially do they regard as exaggerated, not to say useless, the system which has been now and again recommended of "storm-

* "On the Influence of Atmospheric Pressure upon the Volume of Gas issuing from Blowers," *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., page 155.

† "On the Influence of Atmospheric Pressure Variations upon the Evolution of Fire-damp, with special Reference to the Experiments carried out at the Gabriel Pit at Karwin." *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1886, Nos. 3-5.

‡ *Appendices*, vol. I., page 43.

warnings," etc., to be issued to collieries by the Meteorological Office.* Thus in the Final Report of the British Royal Commission on Accidents in Mines issued on March 15th, 1886,† we find the following observations :—

"While we recognise that variations of atmospheric pressure exert influence on the escape of gases which have accumulated in cavities, and possibly to a slight extent on that of gases emitted directly from the coal, we entertain great doubt as to the wisdom of placing reliance on the issue of meteorological warnings. These can at best only convey very imperfect information, which, moreover, may be sometimes dangerously misleading. We are of opinion that safety would be much more likely to be ensured by unceasing vigilance on the part of the officials and workmen in the mine than by any attention to such warnings."

71.—*Temperature.*—While variations of atmospheric pressure act on the whole simultaneously and with fairly equal effect above and belowground, in the matter of temperature we find a fundamental difference in this respect. We know by experience that the influence (upon the air in the pit) of temperature variations in the air above bank vanishes at a very short distance from the downcast shaft, under the influence of the natural heat of the strata. Consequently there is, as a rule, no direct relation between the variations of external temperature and the occurrence of fire-damp in the pit, such as Messrs. Scott and Galloway had conceived (compare par. No. 70 of this Report). On the other hand, a variation in external temperature may indirectly affect the occurrence of fire-damp, in so far as the difference between the temperatures above bank and below bank determines the efficiency of the natural ventilation, and therefore influences the more or less complete prevention of accumulations of fire-damp. And since natural ventilation—even when there is a system of artificial ventilation of the pit—always plays an important part, it would be advisable in all fiery mines to make regular temperature observations, and in accordance with the results deduced therefrom regulate the speed of the ventilator or the draught of the furnace.

The temperature of the fire-damp itself does not generally exceed the highest rock-temperature noted in the particular pit,‡ but in the case of coal liable to spontaneous combustion it may rise far beyond that—at the working-face and in the return airway. Thus Mr. Nasse§ made the following observations at the Gerhard pit, Saarbrück, while the main cross-cut of the No. 5 deep level was being driven from the Josepha shaft to the Beust seam (depth of shaft 784 feet) : the temperature of the strata varying between 17·5 and 18·5 degs. C., that of the air at the face and counterface of the cross-cut was always between 0·2 and 0·9 deg. higher ; after the work of cutting through was finished the rock-temperature in the cross-cut fell by about 0·8 deg., while it fell gradually by several degrees in the neighbourhood of the downcast shaft. In the levels of the Beust seam which abutted on the cross-cut (the coal in this seam is liable to spontaneous combustion) the air-temperature reached 18·5 degs. C., that is, the maximum rock-temperature, but at the working-face the air was 24·3 degs., and in the return current of the main airway as much as 25 degs. was registered, or 6·5 degs. higher than the highest rock-temperature. Using the same method of measurement, Dr. Sattig,‖ at the Camphausen pit, Saarbrück, observed the temperature of the freshly exposed rock in the main

* Sir Fred. Abel, *Address, op. jam cit.*, page 9; *Trans. Manch. Geol. Soc.*, March 2nd, 1886 (On the Karwin Experiments); see *Iron and Coal Trades Review*, March 5th, 1886.

† *Final Report of the British Royal Commission appointed to inquire into Accidents in Mines*, London, 1886 (Blue Book), page 112.

‡ Compare Dr. Serlo, *Treatise on Mining*, 4th ed., 1884, vol. ii., pages 336-338.

§ "Technical Methods of Working the Royal Collieries at Saarbrück," *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiii., page 279.

‖ Mr. Nasse, *op. jam cit.*, page 279.

cross-cut of No. 2 deep level (depth 1,864 feet) to be 34 degs. C.; and in the main gangway, seam No. 3, No. 1 deep level (depth 1,627 feet) to be 32·8 degs. C. (maximum). The air-temperature varied in the working-places of the last-mentioned level between 26 and 31 degs. C., in front of the pillars it varied between 26 and 31·5 degs., and was only 27 degs. in the main return air-current of the whole pit—so that here, at all events, it was possible to have an air-temperature lower than the temperature of the strata.

Such high temperatures of pit air as those above-mentioned in the Camphausen colliery (and very nearly as high temperatures are observed in the working-places in certain Westphalian collieries)* constitute not only an addition to the difficulties which have to be overcome in working, but become in fiery mines a positive danger—because they too frequently induce the pitman to divest himself at the working-face partly or entirely of his clothing, and thus the possible ignition of the gaseous mixtures in the air is fraught with consequences all the more disastrous. Quite insignificant fire-damp explosions have often had a fatal result for the men involved in them, because by partially divesting themselves of their clothing, these men had exposed a larger surface of their bodies (than would have otherwise been the case) to the scorching flame.† These considerations show that it is advisable to watch the temperatures in the working-places, and to lead up to all such points as show a temperature higher than 20 degs. C., a proportionally larger volume of fresh air, so as to keep down permanently the temperature at the working-face.

It was in this sense that the Commission, at their meeting of December 13th, 1884, acceded to the proposals of the Dortmund Local Section, expressed in the following terms :—

"In those pits where the temperature of the working-places underground is shown to be comparatively high, the mining officials should be provided with thermometers; and the temperature at those working-places should be kept down as much as possible by means of reinforced ventilation, so that the pitmen may not be tempted to divest themselves of their clothing while at work."

Whether, moreover, in certain cases, artificial refrigeration of the air by specially devised apparatus (as to which the most diverse projects have been put forth) be advisable or not—is a question the solution of which is largely dependent on local conditions.

In conclusion, it should be expressly observed that the Commission do, of course, entirely agree with the proviso (the observance of which is imperative) in the interest of the general good health of the workers in mines, that in mines where high temperatures prevail the duration of working shifts must not be allowed to exceed a legally-established maximum; see the mining regulations issued by the Royal Mining Bureau, at Dortmund, on June 14th, 1884.

72.—*Hygrometric Condition of the Atmosphere.*—The variations in the hygrometric condition of the external atmosphere have also been frequently invoked as one of the causes which influence the occurrence of fire-damp in mines. But, just as is the case with temperature variations, and for the same reasons as those that were adduced in connexion with them, this influence can only be indirect. It had been known previously, and the knowledge has been recently confirmed by the local sections of the Commission in their journeys of investigation through various pits, that in nearly all collieries the hygrometric condition of the pit air (even when the external atmosphere is very dry) almost reaches saturation point within a very short distance of the downcast shaft. In a few pits only, such as Camphausen (Saarbrück), Maria (Aix-la-Chapelle), and partly Pluto and Neu-Iserlohn (West-

* *Appendices*, vol. ii., page 76. † *Ibid.*, page 77.

phalia), are the working-places remarkable for extreme dryness—yet even here the hygrometric state of the air-current is about 80 per cent. of saturation.* One should bear in mind, however, that this relative dryness—which evidently has nothing to do with the hygrometric variation of the external atmosphere, but depends much on the conditions of stratification and the depth of the workings—favours in a high degree the formation [accumulation] of coal-dust and thereby increases indirectly the risk of explosion. And, as a matter of fact, it is just these very dry pits which have been the scene of most of the great colliery explosions that have occurred in Germany.

Very recently, Mr. Paul Hayn, a mining official at Waldenburg† has sought to prove that the sudden evolution of fire-damp in large quantities when the barometer sinks rapidly is simply due to the concurrent increase in saturation of the external atmosphere. According to his view, the increased quantity of water-vapour conveyed into the mine with the downcast air-current condenses in the pores of the coal, thereby producing heat—and this has for a further consequence the production of pressures which force the [deleterious] gases out of the coal. But this assumption falls at once to the ground, when one remembers the cardinal fact (proved by experience) that the hygrometric condition of the pit air is in no wise subject to temporary variations. Moreover, Mr. Joh. Mayer‡ has already proved in detail that the theory under consideration is absolutely untenable and that the conclusions deduced from it by Mr. Hayn are consequently of no value; we therefore content ourselves with this brief reference to Mr. Hayn's work.

73.—*Weather and Seasons.*—It seems hardly necessary to explain at length that sudden changes in the weather, and other temporary disturbances of the atmospheric equilibrium, such as wind-storms, thunderstorms, etc., may under certain circumstances prove extremely dangerous as regards the evolution of gases in the pit—and that, because they are usually accompanied by brusque barometric variations. It follows that a very large number of the more extensive fire-damp explosions recorded in various countries are held to be nearly connected with such meteorological occurrences.§ Similarly, one would expect to find the evolution of fire-damp more or less dangerous, according to the season of the year; although one must admit that statistical comparisons of fire-damp explosions—whether in Prussia (compare par. No. 27 of this Report), or in Belgium, or in England—afford no absolutely conclusive data in this connexion.‖

Besides the direct influence of the weather which is connected with barometric variations, one must remember the indirect influence exerted by wind-storms or even by the particular directions of the wind—therein that they act temporarily as a mechanical obstacle to the entry of fresh air into the pit and the issue of foul air from the pit.** Of especial importance is this influence in pits which are entirely dependent on natural ventilation, or where in artificially ventilated pits there is only a small depression [water-gauge]; but even with greater depression [water-

* *Appendices*, vol. i., page 167; vol. ii., page 90.

† Mr. Paul Hayn, *Attempt at an Explanation of the Sudden Evolution of Fire-damp in Large Quantities when the Barometer sinks rapidly, and the Conclusions to be drawn therefrom for Purposes of Prevention*, Waldenburg, 1885; *id.* "Contributions towards the Solution of the Fire-damp Question," *Berggeist*, 1885, No. 56, *et seq.*

‡ "Contributions towards the Solution of the Fire-damp Question." *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1885, No. 37.

§ Mr. Gurlt, *The Prevention of Fire-damp Explosions*, pages 26-33.

‖ Dr. Serlo, *Treatise on Mining*, 4th edition, 1884, vol. ii., pages 322-324; see also *Appendices*, vol. ii., pages 2-3.

** Mr. Cornet, "On Pit Gas." *Comptes rendus de la Société de l'Industrie Minérale*, 1881, page 84; Messrs. Mallard and Le Chatelier, *Final Report of the French Fire-damp Commission*; Prof. Kreischer, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. jam cit.*, page 14; *Appendices*, vol. ii., page 214.

gauge] this influence may become a matter of serious import. Thus a self-registering Ochwadt depression-gauge, attached to a ventilator at the Von der Heydt pit, Saarbrück, showed in the most striking manner the effect of a violent wind-storm.* While the ordinary depression [water-gauge] stood at 24 millimetres (about 1 inch) the gusts of wind caused frequent rapid variations between 16 and 32 millimetres ($\frac{3}{5}$ to $1\frac{1}{4}$ inches) or about a third more or less than the ordinary depression. Such extensive variations show how necessary it is, even with artifical ventilation, to observe the influence of the direction of the wind and of wind-storms and as far as possible to combat that influence by running the ventilator at a higher speed or forcing the ventilating furnace, just as in the case of barometric and temperature variations.

74.—*Other Influences.*—In certain communications addressed to the Commission, and in a number of papers which have been published, but are manifestly, as a rule, not the work of practical men,† the attempt has been made to bring evolution of gas in pits and fire-damp explosions into a sort of "relationship of causation" with the most diverse phenomena of the terrestrial globe. By some they are reckoned among the symptoms of the "internal activity of the earth," and are accordingly presumed to be connected with earthquakes, volcanic outbursts, etc.; by others they are believed to have some connexion with electric earth-currents or magnetic disturbances, with the attraction of the moon and the tides, nay, even with the culmination of "solar spot-maxima."

It does not lie within the scope of this report to consider more fully views which may perhaps be best defined "as scientific aberrations." The only one of all these suggested relationships which deserves any recognition at all is that of earth-tremors.‡ But we regard the influence of such tremors as probably restricted to the following effects:—They may cause fissures in the rock which furnish fresh outlets to the imprisoned gases at high tension, and they may occasion falls in old workings whereby gases possibly held back in the roof are enabled to stream forth. Moreover, the British Royal Commission on Accidents in Mines§ regard in their final report, as quite possible the connexion of earthquakes with gas evolution, and thereby the simultaneous occurrence of a number of fire-damp explosions in collieries at some distance from one another would be easily explicable.

6.—*Behaviour and Action of Coal-dust.*

75.—*Former Experiments and Views with regard to the Coal-dust Question.*‖—The fact that coal-dust may largely enhance the disastrous effects of fire-damp explo-

* *Appendices*, vol. v., page 13.

† Baron Gregor Friesenhof, *Can Fire-damp Disasters be Averted? Interdependence of Fire-damp Explosions and Atmospheric Phenomena, and the Possibility of Foreseeing in Good Time the likelihood of such Explosions*, Vienna, 1885; *id.*, *The Safeguarding of Coal-mines against Disasters arising from Fire-damp Explosions, on the basis of the Theory of Tides*, Vienna, 1886; Mr. R. Röttger, *The Weather and the Earth: Meteorology based on New Principles, according to the latest Discoveries*, Jena, 1885; Mr. M. Walton Brown, "On the Observation of Earth-shakes or Tremors, in order to foretell the time of sudden Outbreaks of Fire-damp. *Trans. N. E. Inst.*, vol. xxxiii., page 179.

‡ Compare Messrs. B. de Chancourtois, Ch. Lallemand, and G. Chesneau, "Study of the Movements of the Earth's Crust, with particular Reference to their Connexion with the Evolution of Gaseous Products," *Annales des Mines*, 1886, vol. ii., page 207, *et seq.* A graphical comparison of simultaneous microseismic, barometric, and fire-damp observations made at Douai (Department of the Nord), and in the neighbouring Hérin colliery of the Anzin Company, is given at the conclusion of the above-quoted memoir, page 259, and does indeed show some remarkable coincidences between the intensity of earth-tremors, the fall in atmospheric pressure, and the brisk evolution of gas in the pit.

§ Page 30.

‖ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 52-68, contains a complete bibliography of previous literature on the subject; Sir Fred. Abel, *Report on the Results of Experiments made with samples of Dust collected at Seaham Colliery*, London, 1881; Mr. Nasse, "The Causes of the Principal Fire-damp Explosions in English Collieries during the year 1880, and Abel's

sions is said to have been observed in England as long ago as the beginning of the eighteenth century.* For definite data as to the part thus played by coal-dust we are, however, in the first instance, indebted to Messrs. Faraday and Lyell. These observers, in the course of an enquiry in 1844, into the circumstances of an explosion at Haswell colliery, found in the galleries of the mine layers of partially coked coal-dust; and, after comparing its chemical composition with that of unburnt dust, they were convinced that fire-damp had not been the only combustible factor in the explosion, but that the marsh gas flame (seizing on the coal-dust swept up with the onrush of air) had thereby given rise to the production of enormous volumes of fresh gases which exploded in their turn, and so on, so long as there remained sufficient oxygen for the purpose in the atmosphere of the mine. The same conclusions were deduced from the facts observed in connexion with a number of colliery explosions which took place in France in the course of the following twenty years; and in that country Mr. Du Souich was the first (1855) to express the opinion that coal-dust continues the effect of fire-damp, since it serves to carry the burning gas onward. The first practical experiments made with a view to determining the behaviour of coal-dust were initiated in 1875, almost simultaneously, by the French engineer Mr. Vital and by a committee of the Société de l'Industrie Minérale at St. Etienne, but no absolutely convincing results were attained. To Mr. W. Galloway, colliery manager, of Cardiff, is due great credit for the prominent part he has taken in further elucidating the subject; from 1875 onwards he has made a series of exhaustive researches at the Llwynypia colliery, South Wales, with appropriate apparatus, on the behaviour of coal-dust both in ordinary atmospheric air and in the presence of pit gas.† From his first series of experiments, Mr. Galloway concluded, in 1876, that coal-dust is not inflammable in atmospheric air free from marsh gas at ordinary pressures and temperatures, but that a very slight admixture of gas with the air (1 : 112 or 0·892 per cent. of methane) is sufficient to induce an explosion. The subsequent experiments, particularly those of 1881, modified this conclusion in so far as they showed that many kinds of coal-dust may be brought to ignition in atmospheric air completely free from marsh gas, as a result of shot-firing (blasting) or of a local gas explosion; and the coal-dust is then in a condition, once the fire is thus started, to propagate it of its own accord.

Similar results were obtained by Messrs. Hall and Clark in 1876 in experimenting with "blown-out" shots in a dip-level, the floor of which was strewn with coal-dust, at the Wynnstay colliery. Messrs. Morison and Marreco in the same year also experimented with such shots at the Elswick colliery and reached the same results; so too at Harton colliery in 1878–79, where they used an air-conduit with moving air-currents. Sir F. A. Abel's official experiments at the Garswood Hall colliery in 1880 and 1881, and the very exhaustive investigations conducted by a committee (appointed by the Chesterfield and Midland Counties Institution of Engineers) at

Researches on the Influence of Coal-dust upon Colliery Explosions," *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxx., pages 144-170; Messrs. Mallard and Le Chatelier, "The Part played by Coal-dust in Mining Disasters," *Annales des Mines*, 1882, vol. i.; Prof. Kreischer, "Preliminary Report of the British Royal Commission on Accidents in Mines, *op. jam cit.*, pages 15-17; Mr. Hutchinson, "Notes on Coal-dust in Colliery Explosions," *Trans. Amer. Inst. Min. Eng.*, Chicago Meeting, May, 1884; Mr. Hilt, "The Dangers of Coal-dust with regard to Coal-mining," *Zeitsch. d. Vereines Deutscher Ing.*, 1883, No. 16; *id.*, *Appendices* (to this Report), vol. iv., pages 1-5; Sir Fred. Abel, *Address* of November 18th, 1885, *op. jam cit.*, pages 17-19; Final Report of the British Royal Commission on Accidents in Mines," pages 30-48.

* Sir Fred. Abel, *Address, supra cit.*, page 17.

† Mr. W. Galloway, "On the Influence of Coal-dust in Colliery Explosions," *Proc. Royal Soc.*, March 2nd, 1876, vol. xxiv., page 239; *id. ibid.*, March 13th, 1879, vol. xxviii., page 410; also *ibid.*, June 16th, 1881, vol. xxxiii., page 490 (revised February 10th, 1882); *ibid.*, December 29th, 1881, vol. xxxiii., page 437; *ibid.*, May 15th, 1884, vol. xxxvii., page 42.

the Broad Oaks ironworks during the years 1879-1882, served in the main merely to confirm Mr. Galloway's results. It should be noticed that the reports on the two last enumerated series of experiments do not, on the whole, attribute any very dangerous character to pure coal-dust, provided marsh gas be absent from the circumambient air.

Messrs. Mallard and Le Chatelier,* on behalf of the French Commission, collated and sifted with the most scrupulous care all known records of experiments bearing on the coal-dust question, and they made some experiments of their own, the result of which was that they came, in 1882, to the final conclusion that, although truly some kinds of coal-dust may be ignited without there being any marsh gas present, there is no propagation of the flame by the coal-dust for great distances, even when the percentage of gas in the air is as much as 2 or 3 per cent.

In professional circles, not only in England and France, but in Germany as well, the view thereafter prevailed that coal-dust without fire-damp offers little or no danger; that when explosive gas-mixtures are present, it is only in exceptionally dry mines, and with coal of a peculiar character, that the dust is in a condition to reinforce a fire-damp explosion; while Mr. Galloway's opinion, pointing to the possibility of independent coal-dust explosions, found but little support. Thus, as regarded certain details, the part played by coal-dust in fire-damp explosions still remained an open question, to the further elucidation of which the Prussian Fire-damp Commission felt bound to contribute. The extensive experiments initiated, with that purpose in view, on behalf of the Commission, under the superintendence of our colleague Mr. Hilt, and carried out by the Government Inspector of Mines, Mr. Margraf, at the König pit, near Neunkirchen (Saarbrück coal-field) during the summer and autumn of the years 1884 and 1885, have most fortunately thrown the desired light upon, at any rate, the principal points of the problem.

76.—*Results of the Neunkirchen Experiments.*†—In contradistinction to the English and French experiments, which had been mainly carried out in narrow air-channels, the Commission started on the principle of conducting their researches under conditions as nearly as possible resembling those which would obtain in practice in the ordinary course of working a colliery. And so the experiment-chamber selected was an adit or gallery 51 metres (167 feet) in length, made of elliptical iron rings, with timber lining of the usual measurement (1·72 metres = 5·6 feet in height, and 1·20 metres = 3·9 feet in breadth): at one end of it a masonry wall represented the working-face, whilst the opposite end remained open. For certain series of experiments a short branch gallery (same sectional area) opening out from one side of the first at right angles to it, was subsequently added. For the purpose of firing (blown-out) shots, seven cast-iron mortars pointing in various directions were let into the masonry-wall. A gas-blower of the König pit was tapped to furnish the necessary supply of natural gas (compare par. No. 45 of this Report, analysis xviii.) for the special experiments in gaseous mixtures and with gaseous mixtures.

As new problems constantly cropped up in the course of the experiments, problems of which the solution seemed highly desirable, it was found quite impossible to settle finally all the points which demanded consideration in time for the winding up of the labours of the Commission. At all events, light has been so far thrown on all the points of really essential importance, that it is possible to arrive at a

* "The Part Played by Coal-dust, etc.," *op. supra cit.*; see also *Final Report of the French Fire-damp Commission.*

† Mr. Hilt, "Final Report on the Researches made in the Experimental Drift at the (Government) König Colliery, Neunkirchen (Saarbrück), on the Ignition of Coal-dust and Fire-damp,' *Appendices* to this Report, vol. iv., pages 1-88, and *Trans. N. E. Inst.*, vol. xxxiv., page 199, and vol. xxxvii., abst., page 80.

definite conclusion as regards the main question; while, on the other hand, the path is indicated which one should follow in further special experiments on such particular points as may still remain doubtful.

The more important results of the experiments conducted at Neunkirchen by the Commission may be summarized as follows :—

1.—In ordinary atmospheric air, all varieties of coal-dust are found harmless in the presence of naked lights. Even when the air contains as much as 4 per cent. of methane this harmless character is maintained, for the dust which is swept upward is indeed seen to cause a considerable lengthening of the flame, but does not appear to act as a vehicle for the further spread or onward transmission of the flame. If, on the other hand, the air does contain 4·5 per cent., or more, of methane, certain varieties of coal-dust will induce an explosion in the presence of naked lights; and at a proportion of only 5 per cent. methane this explosion is incomparably more violent than is the case, without coal-dust, with 6 per cent. of methane.

2.—In air free from marsh gas, an ordinary black powder blasting-shot (charged with 230 grammes or about ½ lb.), the flame from which, when the stemming is of clay, extends to 3 or 4 metres (10 to 13 feet), shows, with a stemming made up of a mixture of stone-dust and coal-dust, a flame-lengthening up to 5 metres (16 feet). If the stemming be exclusively made up of coal-dust, the flame extends to between 9½ and 16 metres (31 and 52 feet) according to the quantity of coal-dust used; if the charge of powder be at the same time increased, the flame may extend even to 19 metres (62 feet). The particular nature of the coal-dust used appears to make no essential difference.

3.—The presence of coal-dust within range of the shot (*e.g.*, dust strewn about on the floor of the drift) seems to heighten very considerably the phenomena which have been alluded to. Flame-lengthening takes pplce on a more extensive scale; with certain kinds of dust coal-dust explosions take place, even though there may be no marsh gas present; the coal-dust lying anywhere within reach of the flame shows on its surface formations of coke-crust and coke-beads, while the proportion of volatile constituents originally contained in the dust is found to have decreased in a more or less notable degree.

There are two factors whose influence must be reckoned with in this matter—(1) The state of fine subdivision of the coal-dust, and (2) more especially the chemical composition of the coal. The experiments showed :—

(*a*) That coals poor in gas, containing less than 10 per cent. of volatile constituents, give rise to a tolerably harmless dust, with comparatively moderate lengthening of the flame.

(*b*) That free-burning coal, containing between 10 and 16 per cent. of volatile constituents, occasions flame-lengthening up to 25 metres (82 feet) and perhaps even more if the dust be very finely divided.

(*c*) That bituminous coals, containing between 16 and 24 per cent. of volatile constituents, give rise to flames which extend the whole length of the drift—so far as dust may be strewn—and if the dust be sufficiently fine they very often cause dust-explosions.

(*d*) That gas-coals, containing between 24 and 32 per cent. of volatile constituents, generally give rise to flames the length of which is

much shorter in comparison; and yet, if the coal-dust be very finely divided, the flame will lengthen as far as dust is strewn.

(*e*) That free-burning gas-coal, containing more than 32 per cent. of volatile constituents, occasions, as a rule, flame-lengthening only up to 20 metres (65 feet). But if the dust be very finely divided (an occurrence which, with these coals, will hardly take place unless the coal be broken up for that purpose by artificial means) the flame will, as with other coals, extend as far as dust is strewn.

From the above observations we may conclude that the views which formerly obtained on this point are absolutely unfounded. These views were that only coals containing at least 30 per cent. of volatile constituents give rise to inflammable dust, and that inflammability increases concurrently with the increase in the proportion of the volatile constituents.* The experiments show moreover that serious danger may arise with very much smaller quantities of coal-dust than Mr. Galloway or Messrs. Mallard and Le Chatelier had thought possible. These observers considered that at least 1 kilogramme of coal-dust for every cubic metre of air (roughly 1 lb. in 16 cubic feet) was necessary to give rise to an explosion.†

4.—While, as a matter of fact, very few varieties of coal-dust of themselves give rise to actual danger of explosion in presence of blown out blasting-shots fired with gunpowder—and among the Prussian coal-dusts which were examined this could be predicated only of those from the Pluto and Neu-Iserlohn pits (Westphalia)—as soon as marsh gas occurs within range of the shot, even in so small a proportion as 2 or 3 per cent. (gaseous content of the air), danger of explosion arises with the great majority of coal-dusts. Anthracitic coals alone appear to be comparatively harmless in such cases, although even with them considerable lengthening of flame takes place—and therefore the risk of a fierce conflagration is not entirely shut out.

5.—Blown-out powder-shots in an atmosphere free from marsh gas do not ignite the coal-dust which is strewn about; but if both marsh gas and coal-dust be present ignition takes place so soon as the gas reaches a proportion of 5 or 6 per cent.

6.—High (quick-firing or shattering) explosives are found to be much less dangerous in regard to coal-dust or fire-damp than black gunpowder. It has in particular been proved:—

(*a*) That guhr-dynamite I. (with between 75 and 77 per cent. of nitro-glycerine) ignites the strewn coal-dust neither with ordinary blasting-shots, nor as an unconfined cartridge, provided no marsh gas be present, or provided the gaseous mixture in the atmosphere contains no more than 4 per cent. methane (with "oily" dynamite the safety limit goes up to 5 per cent. of methane).‡

* Messrs. Mallard and Le Chatelier, "The Part Played by Coal-dust, etc.," *op. jam cit.*, page 61, *et seq.*

† *Ibid.*, page 63.

‡ An exception to this rule appears, however, to be afforded by the coal-dust from the Segen Gottes pit (Rossitz Mining Company), in Moravia. This dust is so very easily inflammable that, even though marsh gas be entirely absent, it occasions an explosion if fired by unconfined dynamite-cartridges or blown-out dynamite shots, or "by any hitherto known blasting material whatever." Compare *Appendices* to this Report, vol. iv., page 70, note. See also Mr. R. Schneider, "On Coal-dust Explosions," *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1885, Nos. 7, 33, 34, 41, 42, and 1886, No. 1; *Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, page 35.

(*b*) Blasting-gelatine, gun-cotton, kinetite, hellhoffite—and, according to more recent researches, carbonite and Schultze compressed powder of high shattering power—do not give rise to any danger in presence of coal-dust, whether alone or in gaseous mixtures containing less than 10 per cent. of marsh gas, if they are exploded by means of sufficiently strong detonators.*

7.—Water-stemming gives, with black powder-shots, no assurance of diminution of the risk.†

8.—Ignition of coal-dust may be brought about just as readily by a fire-damp explosion as by a blown-out shot.

9.—Ignition (or explosion) of coal-dust or fire-damp may extend (in a direct line or sideways) by means of travelling over or through accumulations of coal-dust or explosive gases, which accumulations may, however, be separated from one another by an appreciable space. This extension does not only occur when coal-dust or marsh gas is present in the spaces between the accumulations, but may, under certain circumstances, occur when for considerable distances there is no such "train of communication."

10.—The danger of ignition is completely obviated by moistening the coal-dust, but only when the dust is wetted over an appreciable length, say 10 to 15 metres (32 to 50 feet), and when water is used in the proportion of about half the weight of dust.

Not only are the results enumerated above in complete accord with those obtained by the British Royal Commission on Accidents in Mines in the course of the special experiments carried out at Chatham in 1882 and 1883,‡ but they are fully confirmed in all essential points by the experiments which the Royal Saxon mining authorities have recently made (1885) with about one hundred different varieties of coal-dust from various Saxon collieries, at the Brückenberg No. 1 shaft at Zwickau.§

77.—*Explanation of the Action of Coal-dust.*—Judging from the results of the Neunkirchen experiments, the intervention of coal-dust in colliery explosions is in the main due to the evolution of hydro-carbon gases from it by sudden heating.‖ According to the quantity and character of the dust, either these gases may of themselves be sufficient to promote an explosion (coal-dust explosions

* In the course of the experiments conducted by the Royal Saxon mining authorities in the Brückenberg No. 1 shaft, at Zwickau, coal-dust from the Ida shaft, near Hohndorf (Kingdom of Saxony) was in two cases ignited simply by Nobel's gelatine-dynamite, entirely without the intervention of marsh gas. And yet two other experiments in immediate juxtaposition with these, made in the same way with the same dust, showed absolutely no shot-flame, *Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, pages 31-32. At this very Ida shaft, moreover, about the end of the year 1884 and the beginning of the following year, three explosions occurred at short intervals one after the other, and in these cases it was recognized with almost absolute certainty that there had been ignition of coal-dust by gelatine-dynamite, *op. jam cit.*, pages 21, 44-45.

† But it does, as the experiments conducted in Saxony have shown, with dynamite shots. In no single case, out of twenty, where in these experiments dynamite with water-stemming was used, could the marsh gas be ignited, which had been led into the drift till it reached the proportion of 5 per cent. of the air; nor could the coal-dust, which was vigorously stirred up before the shot, be ignited either. See *Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, pages 33-53.

‡ Sir Fred. Abel, *Address, op. jam cit.*, page 18; *Final Report of the British Royal Commission*, pages 36-39, 161-166.

§ "Researches on the Behaviour of Coal-dust at the Experimental Station in the Brückenburg Shaft No. 1 at Zwickau," *Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, pages 21-35. The few exceptions have already been referred to (in footnotes) in the preceding pages.

‖ This hypothesis has been fully confirmed in the course of experiments made with soot and charcoal-dust in the soot factories of the Black Forest in the Grand Duchy of Baden. Compare Mr. Engler, "Contributions to the knowledge of Coal-dust Explosions," in *Die Chemische Industrie*, Berlin, 1885, No. 6, page 171.

properly so-called), or they may at the very least greatly enhance an ordinary fire-damp explosion—they may even render explosive accumulations of pit gas which are not otherwise dangerous, and actually cause them to explode (mixed explosions). Moreover, the coal-dust, once it is stirred up and heated, becomes the actual intermediary, whereby a conflagration of a marsh-gas or coal-dust accumulation at any part of the pit workings may be easily carried onward for almost unlimited distances and set fire to other similar accumulations (double explosions).

But to enable coal-dust to play this dangerous part three contributory conditions are necessary :—(1) the presence of a certain quantity of dust; (2) vigorous stirring up of the same; (3) fire or flame sufficient to heat the coal-dust thus stirred up, so as to cause evolution and immediate ignition of gases. While the first of these conditions is no doubt satisfied in most collieries which are at all dry, the two other requisites only find their complete fulfilment in the case of a blown-out black powder blasting-shot (*Lochpfeifer*) or of a fire-damp explosion which has arisen in the usual way. In the case of blown-out powder shots or of blasting with dynamite or other shattering explosives, a fourth condition appears to be, as a rule, indispensable—and that is the presence of a fairly large accumulation of pit gas (containing at least 4 per cent. of methane). The same condition holds good if ignition of coal-dust is to supervene on exposure of a naked light.

The course of events when coal-dust plays a more or less dangerously active part takes probably the following shape, or at least may be explained on that hypothesis :—

The burning gases evolved from the gunpowder as they burst out of the blast hole, sweep up in a sort of whirlwind the coal-dust lying within reach, and as it is thus brought partially within the area of their heat-radiation it becomes incandescent. This is enhanced, if the blast-hole has been bored in the coal-face, and yet further if the stemming be partly of coal—that is, if the flame of the gases arising from the shot is from the very beginning lengthened by the incandescent particles of coal which it sweeps along with it. As a matter of fact, the flame travels then only with moderate velocity—and so the finer particles of dust which have been swept up (within range) are for several seconds exposed to the flame, an interval of time quite sufficient to allow of evolution of gas from, and coking of, the dust. That this does really take place is proved by the existence of coke-beads and coke-crusts, and by comparative analyses of the original dust and the coke products (diminution of volatile constituents in the dust).*

The dangerous character of the course of events above described increases with the quantity of hydrocarbon gases thereby produced. But the quantity of such gases is dependent for one thing on the mass of dust which has been stirred up and brought within range of the shot-flame; and for another, on the quantity of gaseous constituents in that dust, and the relative ease with which they decompose. In connexion with the first condition the size of the initial flame of the shot is a factor which must be borne in mind, and so it is not difficult to understand how in earlier experiments on a small scale (especially those of Messrs. Mallard and Le Chatelier) mostly negative results were obtained, because there were no flames of large enough spread to distil off from the dust (in a sufficiently short time) so much gas as would bring about a really considerable lengthening of the initial flame. On the other hand, it is equally easy to explain how, under the influence of a violent (though

* In addition to the numerous analyses of this kind made in the course of the Neunkirchen experiments (see *Appendices*, vol. iv., pages 32-33), the analyses of the dust and coke produced an explosion in the fire-damp explosion at the Pluto pit, in Westphalia, on May 10th, 1882, are full of interest (see Dr. Schondorff, *Appendices*, vol. i., pages 35-36). See also the results recorded at the Bettina shaft at Dombrau, Austrian Silesia, on March 27th, 1885 (Mr. J. Spoth, *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1885, No. 36).

perhaps purely local) explosion of fire-damp—instead of the quick-travelling flame from a shot—even from the "lumpiest" coal-slack sufficient quantities of fine dust may be stirred up, and the gases being distilled off from it may act with devastating effect over considerable areas. Moreover, extremely fine division of the dust invariably facilitates stirring up, and thus helps to materially increase the quantity of dust in suspension in the atmosphere, which is simultaneously exposed to deprivation of its gaseous constituents. As to the question of gaseous content and the relative ease wherewith the dust decomposes, evidently those kinds of dust are particularly dangerous, which on rapid heating give off much hydrocarbon gas, but very little water-vapour or other gases containing oxygen. The above considerations enable one to perceive why it is that the dust of many bituminous coals is more dangerous than that of most gas coals.

As a rule, the gases which are evolved from the incandescent dust will immediately take fire, and thereby occasion a more or less considerable spread of the flames proceeding from the blasting-shot. Only a few varieties of bituminous coal-dust appear to decompose with such extraordinary facility that, given the presence of sufficient quantities of dust and of a sufficiently fierce initial flame, the flames are spread with ever-increasing, lightning-like rapidity, causing the formation of a truly explosive mass of gases—which does, as a matter of fact, explode. This we should class as purely a dust explosion.* Dark red, enormous flames, succeeded by thick volumes of smoky, sooty choke-damp, together with formation of coke and soot-encrustations, and the more or less widespread scattering of burnt grains of coal (comp. par. No. 60 of this Report) constitute not only the visible results of an exclusively coal-dust explosion, but enable one to picture exactly the order in which the phenomena took place.

If the previous statement, to the effect that the danger of the part played by coal-dust resides chiefly in the mass of hydrocarbon gases evolved from it by rapid rise in temperature, be founded on fact—there will be hardly any need for an explanation of the further results obtained from the experiments, which show that this danger is much enhanced by the presence in the atmosphere of a certain proportion of fire-damp. It is quite clear that in such cases where the initial flame from the powder-shot is of course bigger and fiercer than in an atmosphere completely free from gas, the coal-dust is acted on with far greater energy, and the evolution from the dust, of a smaller quantity of gas than is usually found needful for the purpose, will suffice to bring about an actual explosion. And, as a matter of fact, the Neunkirchen experiments have taught us that these mixed explosions may take place with almost any variety of coal-dust—anthracitic coal-dusts forming a rather doubtful exception—and with the presence of a very small proportion of marsh gas in the circumambient atmosphere, provided the total quantity of dangerous gases evolved from both dust and atmosphere oversteps a certain limit. Thus we see that coal-dust and marsh gas may, united, help one another to bring about an explosion at times when, taken separately, neither of them could produce any such effect.

* Of the varieties of coal-dust from Germany experimented with at Neunkirchen, only those from the Westphalian collieries of Pluto and Neu-Iserlohn were found to produce a dust-explosion properly so-called) of varieties of coal-dust from other countries this was found to apply only to those from the Segen Gottes pit in Moravia, and the Madeley colliery (England). In working on a large scale such explosions are said to have often occurred at the Segen Gottes pit in particular, see Mr. Schneider, *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1885, No. 7. The great explosion at the Mardy pit, near Cardiff, on December 23rd, 1885, is defined by Mr. Galloway as a true dust-explosion, the principal materials for which were furnished by the accumulations of coal-dust in the haulage-ways, whilst the immediate cause of ignition was a purely local gas explosion occasioned by the naked light introduced into the pit by a stonemason, see *The Western Mail*, January 21st, 1886, art. "Coal-dust as a Factor of Explosions in Coal Mines," and *Berg- u. Hüttenmännische Zeitung*, 1886, No. 31.

And it is just here that lies the great danger of coal-dust in fiery mines, since the best ventilated pits and even such points of the workings as are declared, on examination with the safety-lamp, to be "free from fire-damp," contain as a rule quite enough gas to cause, in conjunction with an easily decomposable, finely-divided coal-dust, a most disastrous explosion—given a concurrence of unfavourable circumstances. According to all appearance many of the more extensive explosions which have occurred recently are due to this cause.*

In contradistinction to true dust-explosions, mixed explosions are conspicuous for the formation of smaller quantities of coke-encrustations; and the smaller the amount of coal-dust participating in the explosion, the smaller is the quantity of coke formed. The presence of a merely insignificant quantity of coke-beads, etc., or their complete absence on the floor, the timbering, or the wall-faces of the workings after an explosion, would therefore lead one to the reasonable conclusion that fire-damp has been the main factor in the disaster.

Finally, as regards the transmission of an explosion from one accumulation of fire-damp or coal-dust to another such, situated at some little distance—the so-called duplex or double explosion: this transmission would seem hardly possible—if the intervening space be entirely free from dust and gas—except over distances which approximately correspond to the "flame-spread" of the first explosion. But these distances may, in certain cases, be really considerable; and it is not in the least necessary that the second explosive accumulation should be in the same direct line of explosion (line of travel) as the first accumulation; in fact, it will explode more easily, if situated laterally (with reference to that line)—provided only that the expansive power of the flame be sufficient to overcome the difficulty of lateral diversion. It is, however, evident that every obstacle in the path of the explosion every diversion or division of the flame, must tend more or less to limit the distance across which transmission of the explosion can take place.

If a merely insignificant quantity of dry coal-dust be present in the space intervening between inflammable accumulations, the flame of the explosion once started is fed in its progress with continually fresh fuel, and is thereby enabled over practically unlimited distances to explode such masses of gas or heaps of dust as may lie in its path. This power of transmission is pregnant with disaster in very dry and very extensive workings, and to it we may fairly attribute some of the worst explosions which have occurred in recent years.†

78.—*Precautionary Measures against the Dangers of Coal-dust.*—The extraordinary dangers with which coal-dust, according to the experiments conducted by the Commission, threatens the miner to an extent previously undreamed of, may be effectively combatted by the application of one of two different methods. Firstly, by scrupulous avoidance of any deposition and accumulation of dry coal-dust in any portion of the workings; and, secondly, by vigilant prevention of such external influences as may serve to stir up and ignite the coal-dust which happens to be lying about in the pit.

With regard to the first point, it is sufficient to observe that an appropriate arrangement of the procedure of coal-working and of coal-loading [into tubs] at the

* Among others we may mention the Seaham colliery explosion in the county of Durham, on September 8th, 1880. There, shortly before the occurrence of the catastrophe, the regulation search for fire-damp had failed to reveal the presence of the gas anywhere in the pit. Thus also the Clifton Hall colliery explosion, near Manchester, in a pit where fire-damp is said never to have been known previously as occurring at all, and where (as a consequence) work was always carried on with naked lights.

† As for instance, the explosion in the Ida shaft, at Hohndorf, Kingdom of Saxony, January 23rd, 1885 (*Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, page 45). And more especially that at the Camphausen colliery near Saarbrück, on March 17th, 1886.

working-face, will be found to result primarily in a considerable diminution of the quantity of coal-dust formed, and secondarily in a restriction of the further spread through the workings of such coal-dust as is formed. But an additional precaution which we would suggest in all dry mines where the coal is of a dusty or dust-forming character is an abundant damping [moistening] of such dust as does occur, for the purpose of rendering it harmless. The ordinary moisture of the pit atmosphere, and even the insufflation of water or water-vapour (steam) into the pit (with the intake air-current) would not be sufficient.* Nor does the strewing of the galleries with powdered rock-salt and soluble potassium salts lead one much farther towards the desired aim.† The only remedy then that remains is the actual spraying of the dust with water; and even this, to be effectual, *i.e.*, to render impossible the ignition of the dust, should (according to the Neunkirchen experiments) be accomplished with an abundant supply of water, corresponding to about one-half of the weight of the dust.

The operation of spraying (which will have the additional effect of cooling the pit-workings by means of water-evaporation) is best done by means of specially-designed portable apparatus; and in dry and dusty coal-mines it should extend, failing absolutely insuperable difficulties, as far as possible through all the main haulage-ways, working-levels, and actual coal-working places. Of what value the application of water can become is instanced by the explosion of December 23rd, 1885, at the Mardy colliery, near Cardiff, a disaster which, according to Mr. Galloway's opinion, was only restricted within comparatively narrow limits, thanks to the circumstance that the workings were now and again watered.‡ The French Fire-damp Commission recommend,§ in accordance with Mr. Galloway's method, for all mines where the coal is apt to give rise to much fine dry dust, firstly, that the main haulage-ways be kept wet or frequently sprayed; secondly, that no blasting-shot be fired in a dry or dusty district until the floor all over that area where the shot might stir up the dust has been carefully watered. But we are unable to conceal from ourselves that so far-reaching a regulation can in practice be properly carried out in only a very few pits, and therefore its universal application is really a matter of impossibility.

In battling with the dangers which arise from the presence of coal-dust, the second method of those above enumerated is that on which the chief emphasis should undoubtedly be laid. We mean the avoidance of those causes which may promote the stirring up and ignition of the coal-dust. The most important of these is shot-firing. We are fain to admit that perhaps no single one of all the various explosives in use in coal-mining, or of those recently experimented with, can under all circumstances be guaranteed to afford complete immunity from dust and fire-damp explosions; and, therefore, probably the safest course in fiery mines would be to suspend blasting operations altogether. The majority of the Commission, however, have not felt justified in recommending the universal suspension of shot-firing, because such a regulation would in many mines raise needless difficulties—difficulties which, apart from their economic bearing (amounting, in some cases, to absolute prohibition of the working of the mine) would, even in the matter of ordinary security, imply a backward step.

* See Mr. R. Schneider, "On Coal-dust Explosions," *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1885, Nos. 33, 34, 41; and Mr. R. Wabner, "On the Prevention of Fire-damp Explosions by means of Water or Steam," *Berg- u. Hüttenmännische Zeitung*, 1885, Nos. 40 and 41.

† *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 206; *Appendices*, vol. i., page 169.

‡ *The Western Mail*, January 21st, 1886, and *Berg. u. Hüttenmännische Zeitung*, 1886, No. 31.

§ *Principles to be Consulted in Working Fiery Mines*, Paris, 1881, chap. iv., "Dusts," sec. 39 (German translation in the *Zeitsch. f. Bergrecht*, 22nd year, 1881, part iv.).

As a matter of fact, the experiments conducted by the Commission, and the results of still more recent researches, demonstrate that in shot-firing actual serious danger of explosion of coal-dust and fire-damp arises only when ordinary, slow-burning black powder is used (and even then only in the comparatively rare event of a blown-out shot). Dynamite and other nitro-glycerine compounds bring about explosions of very few varieties of coal-dust, and then only in peculiarly unfortunate circumstances; while gun-cotton and other modern shattering explosives afford almost complete immunity from coal-dust, and even, perhaps, from fire-damp explosions. This immunity seems, moreover, to be afforded by nitro-glycerine compounds when used with water stemming.

As blown-out shots can hardly be always avoided when black powder is used, the Commission regards the prohibition of shot-firing with black powder as a *sine qua non* in all fiery mines; this prohibition applies to blasting within the coal just as much as to stone-work. On the other hand, we consider that the use of dynamite, etc. (with due observation of certain precautions), is freely permissible in most collieries. Exception should be made only for such districts as show at any particular point, under ordinary circumstances, continual accumulations of fire-damp which are clearly recognizable by means of the ordinary safety-lamp (comp. Art. 19 of the "Principles").

In another portion of this Report we shall resume in greater detail the consideration of the subject of shot-firing.

III.—Causes of the Ignition of Fire-damp.

1.—*The Lighting of Mines.*

79.—*Naked Lights.*—As may be seen from the statistics (compare par. No. 30 of this Report) the actual cause of ignition in no less than 85·3 per cent. of the explosions which took place in Prussian collieries, from 1861 to 1884 inclusive, is traceable to the lights used in the pit; and of the above-mentioned percentage 56·8 is attributable to the use of naked lights. In the overwhelming majority of these cases, the ignition started in portions of the workings where the use of naked lights was the rule—either because those localities were considered to be quite free at all times from dangerous gases, or because the usual preliminary tests with the safety-lamp had given no warning, on the day of the accident, of the presence of such gases. No room for doubt, then, remains that the use of naked lights is attended with serious risk in all collieries, except such as are known by experience and in consequence of the character and lie of the seams to be absolutely free from fire-damp, an immunity enjoyed by some, those of the Upper Silesian coal-field for instance. The risk is emphasized by the result of the experiments made at Neunkirchen (compare par. No. 54 of this Report), showing that ignition and explosion are possible in a gaseous mixture containing a far smaller proportion of fire-damp—4 to 6 per cent.—than had been hitherto thought necessary.

80.—*Safety-lamps.*—Since Sir H. Davy first in 1815, with his wire-gauze safety-lamp, showed in what direction should be sought an efficient protector for the lamp-flame in fiery mines, many have been the improvements and great has been the progress made in the matter of lamps. It must, nevertheless, be confessed that down to quite recent times, the safety-lamp has been far from fulfilling, in regard to its ordinary construction and utility, such requirements as one was fairly entitled to make of it. And, in fact, the statistics already referred to (compare par. No. 30 of this Report) show that in 27·4 per cent. of colliery explosions in Prussia, from 1861 to 1884 inclusive, the ignition of the gases was caused by safety-lamps. The percentage is divisible as follows:—7·1 through unauthorized opening of the lamp, 7·0 through

defects in or damage to the lamp, 1·6 through heating to redness of the wire-gauze, and 11·7 owing to the flame being blown through or passing through the gauze.

Under these circumstances the Commission have thought it advisable to subject the entire question of safety-lamps to a searching technical and scientific examination. They have made it their aim to review as completely as possible the state of matters as regards safety-lamps both in Germany and abroad, to study the results of the many experiments specially undertaken in various countries,* and, on the other hand, by numerous experiments of their own to carry the subject, if possible, some stages farther. Detailed communications regarding this portion of the Commission's labours will be found in the Final Report of the Lamp Sub-Committee.†

Meanwhile, there remains to be considered, the "passing through" the safety-lamp (*i.e.*, the propagation from the inside) of an explosion to the hitherto tranquil explosive mixture; and the "blowing through"—*i.e.*, the mechanical out-thrust of the flame by a more or less rapidly moving air-current.

81.—*Passing through the Safety-lamp.*—By request of the Commission, Dr. Schondorff made an extensive series of experiments in the gas-analysis laboratory at Bochum; ignition was effected by the electric spark, and the mixtures experimented on sometimes contained ordinary illuminating gas and sometimes pit gas.‡ On the whole, the results of these experiments confirm the observations of Mr. Marsaut, as well as those of Messrs. Mallard and Le Chatelier; they prove indeed that passing through may be more or less easily induced by internal explosion in all known forms of safety-lamp (the Davy lamp resisting best, the Boty lamp next best, and the Mueseler hardly so well), but that in this connexion mixtures containing pit gas are incomparably less dangerous than those containing illuminating or coal-gas. Given, in fact, the normal conditions which in practice obtain in colliery-working, "passing through" need scarcely be feared in any of the three varieties of lamps named in atmospheres containing fire-damp—the case of sudden blowers or outbursts of gas being expressly excepted.

For details the reader must be referred to Dr. Schondorff's reports§ and to the statement of principles, based thereon, enunciated by the Lamp Sub-Committee.‖ Meanwhile, the most important conclusions from the practical point of view may be stated as follows:—

1.—A lamp without a glass chimney (Davy lamp) is far less liable to passing through than a lamp which has a glass chimney. Under like circumstances the safety of all lamps increases in direct ratio of the surface of the wire-gauze and in inverse ratio of the cubical content of the lamp; it increases also inversely as the ratio of the glass-chimney cubical content to the total content of the lamp.

2.—Given the same surface of wire-gauze, a conical shape is safer than a cylindrical shape. Sudden narrowings or constrictions (alterations of diameter) favour passing through.

* Among the most important of these may be mentioned the experiments of the Belgian Lamp Commission, of January 20th, 1868 (*Ann. des Travaux Publ. de Belgique*, vol. xxxi., pages 306, 516); the labours of the French Fire-damp Commission (Messrs. Mallard and Le Chatelier, "On Safety Lamps," *Pièces annexées de la Commission*, and *Annales des Mines*, ser. 8, vol. iii., page 35); of Mr. Marsaut, *Treatise on the Miner's Safety-lamp*, Alais, 1883; the experiments of the British Royal Commission on Accidents in Mines (Prof. Kreischer, "Preliminary Report," pages 17, 36, etc., also *Final Report* of that Commission, Appendix xxiv.); the experiments conducted by the Midland Institute of Mining, Civil, and Mechanical Engineers at Aldwarke Main Colliery; and finally Messrs. Kreischer and Winkler's "Researches on Safety-lamps" (*Jahrb. f. d. Berg-, u. Hüttenwesen im Kgr. Sachsen*, 1884).

† *Appendices*, vol. iii., with atlas of plates.

‡ *Ibid.*, vol. iii., page 121, *et. seq.*

§ *Ibid.*, pages 142-159.

‖ *Ibid.*, pages 177-180.

3.—As regards the texture of the wire-gauze, safety increases inversely as the width of mesh—so that, given the same thickness of gauze, the closer the mesh the safer is the lamp; or, given the same closeness of mesh, the thicker the gauze the safer is the lamp.

4.—Admission of air from below considerably increases the liability of a lamp to passing through. Air-rings with a covering of wire-gauze are preferable to perforated rings. In the latter, the danger of passing through increases directly as the diameter of each of the perforations. The chimney peculiar to the Mueseler lamp favours passing through. (Air being admitted from below, there is a continuous streaming through the entire lamp of the dangerous gases, while the gaseous products of combustion are rapidly displaced; air being admitted from above, the lower part at all events of the glass chimney remains filled with the gaseous products of combustion—and these have a favourable effect, for while indirectly they tend to decrease the mass of disposable oxygen, directly they help to diminish the violence of a possible explosion by acting as an elastic cushion or buffer.)

5.—By making use of several superimposed cages of wire-gauze (Marsaut lamp), the risk of passing through may practically be reduced to vanishing point.

82.—*Blowing through the Safety-lamp.*—It is a well-known fact that violent motion of a safety-lamp, or air-currents moving with great velocity are sufficient to drive the flame of the lamp outwards through the wire-gauze and thus to bring about fire-damp explosions. It has already been the object of manifold experiments not only in Belgium, in England, and in France, but among ourselves in Germany. The results of our countrymen's experiments show that the risk of blowing through begins soonest in the Davy lamp (at an air-velocity of less than 2 metres [6½ feet] per second); the Mueseler lamp shows decidedly greater powers of resistance, provided the air-current does not strike the flame at an angle [steeply inclined] or direct from above downwards, in which case blowing through almost invariably follows. An adequate degree of safety in ordinary circumstances is attained by a protective hood, such as Mr. Marsaut used first in his lamp, and such as may be affixed to all safety-lamps in one form or another as a shut-off—see, for instance, the proposals of the British Royal Commission.*

The experiments on blowing through, conducted by Dr. Schondorff in the gas-analysis laboratory at Bochum,† admit, moreover of the following conclusions:—

1.—In blowing through (just as in passing through) mixtures containing illuminating gas are decidedly (one-and-a-half times) more dangerous than those containing pit gas; in the latter, blowing through does not take place with less than 7·5 per cent. of methane.

2.—The risk of blowing through increases, not only in the direct ratio of the velocity of the air-current, but also on the one hand directly as the amount of gas present in the atmosphere (and here the maximum effect is attained before the mixture reaches its most explosive percentage), and, on the other hand, directly as the sectional area of the current. The voluminous air-currents, with which one has almost invariably to deal in collieries, may therefore be expected to blow through at a lower velocity and in a gaseous mixture containing less than the 7·5 per cent. of methane (arrived at by the experiments).

* *Final Report*, pages 68 and 118.

† *Appendices*, vol. iii., pages 159-165.

3.—The risk of blowing through decreases as the thickness or closeness of the wire-gauze increases. Double wire-gauzes are safer than single ones, but even their resistance is not of a very permanent character, because the inner gauze (being brought to a state of incandescence by the rush of air-currents) itself falls an easy prey to destruction, or is the cause of the fracture of the glass chimney.

It must be noticed, however—and to this Dr. Schondorff very properly calls our attention—that the risk of blowing through in a safety-lamp need not give rise to overmuch anxiety on the part of the cautious and clear-headed miner; since, as a matter of fact, blowing through cannot happen until the wire-gauze has attained the precise stage of incandescence requisite therefor—a process which takes more or less time. During this preliminary period, the one-sided glow of the lamp acts as a safety-signal or warning beacon impelling one to protect the lamp, either by means of the clothing or by changing the position of one's body, against the in-blowing air-current.

83.—*Ignition of Fire-damp arising from Incandescence of the Wire-gauze or the Damaged Condition of the Lamp.*—Apart from the effects of blowing through, which have just been considered, the wire-gauze may be brought to a dangerous state of incandescence, either by the lamp being held in an inclined position, or by the whole space within the gauze being (in strongly explosive mixtures) filled with flame during an appreciably long interval of time. But, according to the extensive series of experiments conducted by Dr. Wüllner and Dr. Lehmann (compare par. No. 57 of this Report), in all the cases known, it is hardly so much the incandescent gauze itself which causes ignition of the external gaseous mixture, as the circumstance that the wire-gauze is gradually destroyed during incandescence, and the protection or safety hitherto afforded by it to the lamp is of course reduced thereby to *nil*. Here, just as in the case of blowing through, the observant miner will be almost invariably in a position to avert disaster by taking timely precautions.

Risks may continually arise, moreover, from external damage to the wire-gauze (in particular, from widening of individual portions of the mesh, or injury to the connexion betwixt wire-gauze and glass chimney), from defective fitting together of the various parts of the lamp (so that they work loose), and finally from sudden fracture of the glass cylinders—because these various defects offer so many unprotected openings for the ignition of fire-damp. On the other hand, Dr. Schondorff's experiments demonstrate that even a partial plugging or choking up [smearing with some foreign substance?] of the wire-gauze surface, and particularly over its lower portion, seriously diminishes the safety of the lamp; and for the reason that not only is the effective surface of wire-gauze reduced, but under apposite conditions, incandescence of the gauze is thereby promoted and heightened. Common sense should therefore urge the miner, so soon as any defects such as those above-mentioned are observed, to immediately put the lamp aside or extinguish it.

84.—*Ignition of Gaseous Mixtures by opening a lighted Safety-lamp or re-lighting one that has been extinguished.*—With the view of preventing the possible ignition of fire-damp by unauthorized opening of the safety-lamp in the miner's hands, the lamps are very often so fitted that the flame is automatically extinguished by the mere act of opening them. But this arrangement is at once confronted by the objection that it sorely tempts the miner to relight the extinguished lamp by any flame-giving means that happen to be available. A really practical precaution against this danger consists in using some reliable safety-lamp lock, which cannot be tampered with, or which at least makes the task of unnecessarily opening the lamp a hard one.

It is unfortunately true that none of the safety-lamp locks, introduced of late years and tested by the Commission, appear able to resist with absolute success the deftly-contrived "dodges" invented by certain individuals for opening them unperceived. But, at all events, on the supposition that sufficient control is exercised by the mining officials, most of these locks would in practice fulfil the purpose for which they are made, especially if, besides acting as locks, they tend to make the various parts of the lamp fit closer together.

In the nature of things, the re-lighting of extinguished safety-lamps in fiery mines is quite as objectionable as the opening of lighted lamps—unless the operation of re-lighting is performed at a station which is known to be absolutely free from fire-damp. Experience shows that the number of lamps extinguished by various causes, in the course of a single shift, is very considerable. Statements which are the result of detailed enquiries put the percentage for some mines as high as 20—that is, 1 in every 5 lamps used, nay, even higher still.* The dangers which arise from re-lighting demand, therefore, some consideration. Among the means devised to meet the risk is the provision in the pit of spare lamps ready lighted, or the fitting up in a safe part of the workings of a lamp-station, whither all lamps that are extinguished must be brought for opening and re-lighting. Better still, so it appears to us, are the recently-invented "lighters" affixed to certain lamps—such as the Wolf percussion-lighter or the Pieper electric-lighter,† which allow of the lamp being re-lighted when extinguished without there being any need to open it. Especially does the percussion-lighter connected with the Wolf benzine-lamp, now that its initial imperfections have been made good,‡ seem destined to be used with great advantage in the practical working of collieries. And, though the experiments of Dr. Schondorff demonstrate that, in mixtures which contain ordinary coal-gas, the percussion-lighter is far more dangerous than the electric-lighter,§ the still more recent experiments of Dr. Broockmann‖ afford unmistakable proof that the improved Wolf percussion-lighter does not give rise, in natural mixtures containing fire-damp, to the slightest danger of "passing through," even when these mixtures have the most explosive percentage composition.

85.—*Illuminating Power of the Safety-lamp.*—The wire-gauze of safety-lamps, however essential in the matter of diminishing the risk of ignition of fire-damp, has the very grave disadvantage that it reduces considerably the illuminating power. Nor is the disadvantage entirely obviated by the substitution of a glass-cylinder for the lower portion of the wire-gauze. Even the best glass-cylinder lamps now in use fail to give as brilliant a light as might reasonably be expected. The experiments on this subject conducted by the Commission have shown that the average illuminating power of a Davy lamp represented 20 per cent. of one English normal sperm candle-power with a flame-height of 45 millimetres ($1\frac{4}{5}$ inch); that of the numerous glass-cylinder lamps which were tested varied between 31 and 88 per cent. (with an average of about 60 per cent.); while the ordinary naked lights used in the pit represented 140 per cent. [of the same unit].** And then it must be

* *Appendices*, vol. iii., pages 13-23.

† See detailed description in the *Appendices*, vol. iii., pages 24-28.

‡ Among these imperfections were the insufficient strength of the strips of paper and small size of the percussion-caps which rested on them, the general weakness of the mechanism and of the percussion striker: the result was that the apparatus often failed to work, or, after several unsuccessful attempts at lighting had been made, several percussion-caps would "go off" together. To an occurrence of this nature is attributed, among other accidents, a fire-damp explosion which took place on July 5th, 1886, in the Maria pit at Hongen (Aix-la-Chapelle). By using stiffer strips of paper, with bigger and more regularly arranged percussion-caps, and by perfecting generally the mechanism of the apparatus, Mr. Wolf has been able to remedy the above-mentioned defects.

§ *Appendices*, vol. iii., pages 166-167.

‖ *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., page 323.

** *Appendices*, vol. iii., pages 110-121.

borne in mind that this maximum illuminating power is only attained at the beginning of the shift, and after a preliminary cleaning of the lamp; but that, as the lamp gets encrusted with soot and dirt in the course of the shift, the initial lighting power of the lamp is gradually reduced, sometimes to as little as one-half, or even less.

There is no room for doubt that the serious increase which has been noted of late years, of various ophthalmic affections among coal-miners,* is, above all things, traceable to the feeble illuminating-power of the safety-lamps. The unsatisfactory character of the light naturally gives rise to various accidents, as in cases of fall of rock, etc., and, moreover, it tempts the miner to open the lamp in defiance of regulations, and thereby leads to fire-damp explosions. From both points of view we are, therefore, impelled to make an urgent recommendation that a definite minimum illuminating-power be fixed—reckoned for ordinary conditions to last during the whole course of the shift—as requisite in all safety-lamps which are used for actually working the mine.† The minimum which the Commission deem it advisable to propose would be 60 per cent. of one normal candle-power, corresponding to 80 or 90 per cent. of the initial illuminating-power at the beginning of the shift.

The attempt to obtain this heightened illuminating-power by the application of reflectors or glass lenses (an idea which was to a certain extent carried into effect by Sir H. Davy himself) appears hardly suitable for working-lamps, because, by such methods, the light is strengthened towards one side only, and thus a complete simultaneous view of the whole working-place (with the lamp in hand) is rendered impossible. The aim towards which our efforts must tend will be best fulfilled by improvements in the shape of the various lamps already in use, and by introducing perfected illuminating agents (lighting material).

In the first place, the experiments conducted by the Commission show that the differences in illuminating-power, as between the various systems of safety-lamps, are by no means so striking as the differences noted in individual applications of one and the same system. It follows, then, that, for each system, at least the maximum illuminating power attained in the experiments may be secured by appropriate construction of the lamp, by the use of good materials and careful workmanship. And, in fact, many of the sample lamps latterly submitted to the Commission by various manufacturers have been shown to be possessed of the necessary conditions of safety, together with an illuminating-power of a really satisfactory character. One thing alone remains, and that is, that managers of collieries in purchasing lamps should, in future, make their requirements more stringent than has hitherto been the case as regards illuminating-power, and insist on those requirements being complied with.

Turning now to the illuminating agent utilizable in safety-lamps, preference was given (until quite recently) to refined rape-oil, and only now and then was the illuminating-power heightened by the addition of petroleum. Latterly, more attention has been paid to mineral-oils, as giving better light. And especially has the use of the Wolf benzine-lamp in the course of a very short period of time spread through almost all the coal-mining districts of Germany. According to the universally concordant experiences of mining officials, and also according to the experiments carried out by the Saxon and Prussian Commissions, this lamp compared with the rape-oil lamp gives a much clearer and more constant light; the wick needs no trimming, and the various parts of the lamp do not get encrusted with grease or

* Particularly among the miners of the Bochum and Saarbrück coal-fields.

† In examining the workings for fire-damp, Davy lamps, in spite of their poor illuminating power, should still be used, for reasons that will be explained later.

soot. Moreover, the lighting apparatus affixed to the lamp (compare par. No. 84 of this Report) has the great advantage of enabling an extinguished lamp to be re-lighted without opening it. One must, of course, admit that continual use of the percussion-lighter promotes a "jar" of the inner surface of the glass-cylinder. The many dangers at first feared as necessarily consequent upon the use of benzine, are now proved by much experience to amount to very little indeed—provided always that a good article be used, and that the most ordinary precautions be observed in the matter of storing the benzine and filling the lamps. And so the complaints which are occasionally audible, as to diminishing illuminating-power and deleterious vapours of the benzine-lamps, may be referred according to the detailed and extensive researches of Dr. Broockmann simply to the use of bad benzine.*

86.—*Regulation Safety-lamp.*—As a summary of the results of their experiments and deliberations concerning the construction of safety-lamps, the Commission deem it advisable to set forth as follows the requirements which in their opinion should be demanded, for the security of miners, of all safety-lamps (Art. 21 of the "Principles" enumerated farther on):—

(*a*) The enclosure of the combustion-chamber should be so arranged and maintained, that at no point would the combustion-chamber be in communication with the outside air by an opening of larger area than 0·0004 square inch (0·25 square millimetre).

(*b*) The wire gauze must be evenly woven throughout of wire of, say, 0·37 to 0·42 millimetre fineness (0·0146 to 0·0165 inch), and the sectional area of each portion of the mesh should not be greater than 0·25 square millimetre (0·0004 square inch).

(*c*) Every safety-lamp must have an illuminating power of at least 60 per cent. of one normal candle-power. It is, however, permissible in searching the workings for fire-damp to make use of lamps of lower illuminating-power.

(*d*) Every safety-lamp must be so built that its component parts fit tightly and intimately together.

(*e*) The lamp must be provided with a lock of such character as to enable the question of opening it to be brought within the range of easy control, and such as to secure the perfect interlocking of the component parts.

Further, with regard to the fitting up of the lamp the following recommendations are made (Art. 22 of the "Principles"):—

(*a*) The air necessary for combustion should, in lamps provided with glass-cylinders, be led in from above downwards.

(*b*) The glass-cylinder should possess a perfectly even wall-thickness throughout, and should consist of glass of the best quality and most carefully annealed. Its edges must be ground exactly horizontal and at right angles to the axis of the lamp. It should measure in height 54 to 60 millimetres (2·12 to 2·36 inches), in average diameter 40 to 50 millimetres (1·57 to 2 inches), in wall-thickness 6 to 8 millimetres (about 0.24 to 0·32 inch).

(*c*) The wire gauze should measure in height 95 to 105 millimetres (3·74 to 4·13 inches); it should not be narrower in its lower portion than the glass-cylinder, and its upward tapering should not be greater than 10 millimetres (0·39 inch).

* Dr. Broockmann, "On Benzine and Benzine Safety-lamps," *Zeitsch. f. d. Berg-, Hütten-u. Salinenwesen im Preuss. Staate*, vol. xxxiv., pages 320-324. The requisites of good benzine, according to this author, are that it should "contain no constituents which boil below 60 degs. C., nor any which, after the lamp has gone out of itself, remain behind in the benzine reservoir and are recognizable by their strong odour of petroleum."

Of all the various forms of lamps hitherto in current use, no single one can be pointed to as fulfilling all the above requirements. Very many of these lamps indeed do not comply with the strict observance of the fundamental principles of the Davy lamp—nor do they offer any entirely satisfactory substitute for those principles. Other lamps again are objectionable because of their too great liability to "blowing through" or "passing through," or because of too low a standard of illuminating-power; and yet again others are objectionable because they are apt to be too easily extinguished, and very many others because they are built on lines far remote from that simplicity which is the prime condition required of lamps for everyday use in the pit.

But though, as we have just seen, no lamp hitherto in use can be recommended as a model for imitation, the Commission have felt that the purpose in view would not be advanced by definitely prescribing a model lamp of unalterable make as the lamp to be universally used in fiery mines. A suggestion of that kind would indeed tend to defeat its object, for it would constitute a serious hindrance to further improvements, to further progress in the matter of safety-lamp construction. Nevertheless the Commission have availed themselves of the opportunity of devising a sort of regulation lamp on the basis of the above-enumerated requirements and recommendations, and they had intended to submit that lamp to very detailed experimental investigation. Circumstances beyond their control have unfortunately prevented them from carrying on these experiments to an extent sufficiently great to warrant them in drawing conclusions of practical importance therefrom.

87.—*Electric Lighting.*—The use below ground of the electric light is not attended with any serious risk in fiery mines, provided that the wires which carry the current and the individual lamps are protected by adequate coverings, and that the current strength used is not too considerable (compare par. 56 of this Report). Indeed, from the mere point of view of security, electric incandescent lamps would be infinitely preferable to the ordinary safety-lamps. And if, notwithstanding [its known advantages], the electric light has only here and there, in a few isolated localities, come into use in fiery mines, the reason is simply that, however conveniently it may be applied to stationary lamps in shafts, in loading-places, nay even in main haulage-ways, failure has hitherto attended all attempts to provide a portable electric lamp, sufficiently simple, long-burning, and cheap, to be used as a satisfactory substitute for the ordinary safety-lamp at the working-face. Still, we are not unmindful that very recently certain successes have been won in this field, which fill us with the hope that sooner or later a practical electric miner's lamp will be devised and made.

The connecting of portable electric incandescent lamps to a circuit used for the supply of stationary lamps, or to a wire led directly into the working-places, was first tried in 1881 at the Pleasley colliery near Mansfield, and at the Earnock colliery near Hamilton.* But the dependence of the lamps on the conducting-wires was as a rule found to be impracticable under the ordinary conditions of coal-working and coal-haulage, conditions which make it requisite that the lamps should be freely movable. There remains then the one resource of battery currents or accumulators.

Apart from the older Dumas-Benoit photo-electric safety-lamps† with Geissler tubes (which, on account of their low illuminating power need not be considered

* Compare *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxx., pages 335-338; also *Final Report of the British Royal Commission on Accidents in Mines*, page 93.

† Compare *Bull. Soc. de l'Industrie Minérale*, series 1, vol. ix., page 1, and *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xiii., page 97, *et seq.*

here), many lamps of that kind, all of them incandescent, have been brought forward in recent years.* Worthy of particular mention among these are, on the one hand, the lamp of Mr. Trouvé of Paris† and that of Mr. K. Blänsdorf of Frankfurt a/M,‡ which have been the subject of successful experiment in the Government collieries at Saarbrück; and on the other hand, the incandescent lamps submitted by Mr. Swan to the British Royal Commission on Accidents in Mines, and, recently vastly improved and perfected by their inventor.§ The last-mentioned Swan lamp, for handiness and light-duration, as well as for prime cost and upkeep, appear to be that which most nearly approach the ordinary safety-lamp. In any case, portable electric lamps offer great advantages for rescue work and similar operations which are out of the ordinary course—especially when one considers that they are the only or as yet the most perfect known illuminating agents for use in atmospheres of fire-damp or unbreathable gases.

2.—*Shot-firing* (*Blasting*).

88.—*General Considerations.*—On account of the production of flame which is a consequence of every shot fired, the operation of blasting in the presence of inflammable gases is invariably attended with more or less grave risk. And, in fact, concurrently with the increased application of blasting to purposes of coal-mining within the last ten years, the number of fire-damp explosions originating from blasting shots has not only very much increased actually but also proportionately to the total number of explosions from all causes. Thus it is that, of the fire-damp explosions which are stated to have occurred in Prussian mines within the period 1861-1881, the yearly average of cases traced to blasting was 7·4 (or 12·9 per cent.), whereas in the years 1882-1884, the yearly average leaped up to 27·3 cases (or 19·7 per cent.); the total number of explosions thus caused in the twenty-four years 1861-1884 was 237, and the average for the whole of that period was 14·6 per cent. (compare par. 30 of this Report).

The ignition of fire-damp may ensue as a direct consequence of blasting in either of two ways:—(1) from the lighting materials used for igniting the shots, or (2) from the flame which arises on the explosion of the blasting material itself. In the first case, the area of ignition is, as a rule, limited to the immediate neighbourhood of the burning fuze; but in the second case the area of ignition is incomparably wider and varies according to the character of the explosive, the heavy loading or otherwise of the shot, the nature of the stemming, and so on—because, according as the case may be, the flame from the shot is able only to seize upon the gases in proximity to the borehole (ordinary effective shot), or the tongue of flame darts off on its errand of ignition to greater distances (overcharged or blown-out shot). To the above considerations we may add that the danger is much enhanced by the concussion of the air which takes place (almost) simultaneously with the firing of the shot. This concussion may impel towards the area of ignition

* *Final Report of the British Royal Commission on Accidents in Mines*, pages 93-97.

† *Comptes Rendus Soc. de l'Industrie Minérale*, 1884, page 180; *Glückauf*, 1884, No. 88; *Berg-, u. Hüttenmännische Zeitung*, 1885, page 309.

‡ The Trouvé lamp (furnished by Mr. H. Flottmann of Bochum) when filled weighed 3½ kilogrammes (8 lbs.), burnt for two hours with 4½ normal candle-power, and cost £3 2s. 9d.; the corresponding figures for the Blänsdorf lamp are $3\frac{1}{10}$ kilogrammes (7 lbs.), 1½ hours, 3½ to 4½ candle-power, and £2 10s. Both lamps had bichromate batteries.

§ *Final Report of the British Royal Commission on Accidents in Mines*, pages 94-96 and Appendix xx.; *The Iron and Coal Trades Review*, Nos. 972, 981, vol. xxxiii. (1886), pages 563, 877. The improved lamp (with battery) weighs 5¾ to 6¼ lbs., and burns with more than 1 candle-power for the whole duration of the shift. Its prime cost is about £2, and upkeep (including 10 per cent. written off for depreciation) at most 4½d. per week.

further masses of imflammable gas (coming from the roof, or the goaf, or from fissures), or sweep up into it small tornadoes of coal-dust; or again, the concussion may cause the "blowing-through" of safety-lamps, an occurrence which may take place, according to Mr. Galloway's experiments, even in parts of the workings fairly remote from the centre of disturbance.*

In the natural order of things, blasting entails the actual explosion of only such gases as are already sufficiently mixed with air. Supposing that the firing of the shot itself unlocks, as it were, new reservoirs of gas, the gases which stream out of them may indeed participate (in small quantity) in the explosion—but this explosion, on account of the deficiency of oxygen, will not make its way farther into the rock. On the other hand, it is a by no means uncommon occurrence that blowers (fired against by chance) are ignited by a shot, and then quietly burn themselves out; just as sometimes, in rock which contains an unusual amount of gas, there has been observed after shot-firing an ignition and long-comtinued burning away of the whole loosened mass (compare par. 65 of this Report).

89.—*Shot-lighting Materials.*—After what precedes it is unnecessary, we should think, to set forth in so many words that, in the presence of fire-damp, the ignition of blasting-shots by means of naked lights or any flame-giving fuze is to be absolutely deprecated on principle. As a matter of fact, the mining regulations of most foreign countries, as well as of our own, do expressly provide that in mines where safety-lamps are in ordinary use, if blasting by shots be at all permissible, the shots shall be fired only by such materials as burn without flame. The regulation is usually so far complied with that an untarred fuze is employed, reaching into the cartridge (where dynamite, etc., is used, in combination with detonators), and is ignited by steel, flint, and tinder. Rarely are electric lighters employed.

As to the fuze-tape, the experiments carried out at Neunkirchen by the instructions of the Commission have shown† that, at the moment when the spark from the tinder touches the powder-core of the fuze, there arises a small sputtering flame which lasts for about two seconds, and the same occurrence is perceptible at the end of the fuze, as well as at all points where cuts have been made in the fuze (*e.g.* wherever the tape being damaged the powder-core is laid bare, but not where the fuze has only been sharply bent or twisted). The experimenters failed to produce on any occasion direct ignition of fire-damp or coal-dust by the smouldering tinder. Nor had the above-mentioned sputtering flame any such effect on mixtures of pit-gas up to 4 per cent. of methane (even when coal-dust of the most dangerous description was present as well), but it did ignite gaseous mixtures containing 5 per cent. (and more) of methane in presence of coal-dust, and mixtures containing 6 per cent. of CH_4 and upwards in the absence of coal-dust. If the sputtering flame (end of the fuze with tinder) happened to arise in an atmosphere free from gas no explosion ever followed, not even when in the neighbourhood of the borehole gaseous mixtures were present containing as much as 8 per cent. of methane.

Moreover, the Neunkirchen experiments lead one to infer‡ that of themselves the fulminate-of-mercury caps which are used for blasting with dynamite, etc., do not, when exploding, ignite even the most dangerous gaseous mixtures, nor do they ignite coal-dust. At any rate, the most potent percussion-caps of that description that were experimented with ("double-force" of Messrs. Nobel & Co., "triple-force" of Messrs. Bornhardt, as well as the gun-cotton-kinetite caps of Messrs. Petry and Fallenstein), being discharged by means of electricity, failed on every occasion, even with 8 per cent. of methane and with the simultaneous presence of coal-dust,

* See Dr. Serlo, *Treatise on Mining*, 4th edition (1884), vol. ii., page 227.

† *Appendices*, vol. iv., pages 72 and 87. ‡ *Ibid.*, pages 73 and 87.

to bring about ignition (of the gaseous medium). On the other hand, the Abegg capsules, which contain, among other things, a certain quantum of fine-grained gunpowder, though they failed to originate a coal-dust explosion, did cause ignition of a gaseous mixture with as little as 5 per cent. of methane.

Many objections have been raised against the practice of procuring ignition by means of flint and steel, partly because the experiments of Messrs. De Villaine and Griot showed that the resulting sparks are capable of setting fire to illuminating gas, and partly because the old steel-mill (*gallicé* "rouet à silex," *germanicé*, "Feuersteinscheibe" or "Stahlmühle") formerly used in Britain and in Belgium (which certainly produces regular showers of brilliant sparks), was, as a matter of fact, the determining cause of more than one fire-damp explosion.* The series of special experiments, which the Prussian Commission originally proposed to make on this very subject, were ultimately dispensed with, on its being shown, in the course of the experiments carried out at Aix-la-Chapelle by Drs. Wüllner and Lehmann "on the inflammability of explosive gaseous mixtures by incandescent wires or by the electric spark," that even the intense scintillation of sparks with which iron burns away (in oxygen) had no effect as to the ignition of such mixtures.†

Comparatively speaking, ignition by electricity must be regarded as the safest mode of firing shots in fiery mines. It has indeed been proved by Mr. Joh. Mayer‡ that complete immunity from danger in that respect can only be secured by laying the conducting-wires in the most careful way, and by exercising minute and unwearied supervision over the "shot-firing machine" itself. In practice, ignition by electricity has not been hitherto adopted in fiery mines to any extent worth mentioning. One chief reason is, perhaps, that the lengthy conducting-wires necessary for joining up the borehole with the "shot-firing machine" are a nuisance in the workings; another drawback is that, where the working-face is wet, the action of the "electric shot-firer" cannot be depended on. Then, too, the advantage which this system offers, say in shaft-sinking, of firing several shots simultaneously cannot, in the ordinary course of coal-working be made any use of.

So-called ignition by friction, as used in artillery practice, but suitably modified for blasting purposes in fiery mines, has recently been proposed by Colonel J. Lauer. The process has been repeatedly experimented with in the Ostrau-Karwin coal-field, and we are informed that it is absolutely harmless in presence of fire-damp, that it is far more trustworthy than the electric method, and that to these advantages it adds the merits of cheapness and simplicity.§

90.—*Explosives.*—The possibility of the ignition of fire-damp by the flame that proceeds from a blasting-shot depends largely on the volume of that flame. Now, the extent of the flame is conditioned merely by the lapse of time necessary for the complete combustion or gasification of the explosive; indeed, the flame grows—contrariwise to the actual blasting effect—in the direct ratio of this lapse of time—or, what comes to the same thing, in the direct ratio of the extent to which the individual particles of the explosive on their decomposition incandesce and give rise to combustible gases.

Ordinary black gunpowder burns away slowly, and it is a well-known phenomenon with fire-arms, just as with "blown-out shots," that burning and even unburnt grains of powder are swept forth with the tongue of flame which

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, original pages 124 and 153.

† *Appendices*, vol. iii., page 200.

‡ *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1887, No. 11.

§ Mr. Joh. Mayer, "J. Lauer's Process of Ignition by Friction for Blasting Shots in Fiery Mines," *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1887, No. 11. The patent taken out for this process is described in detail in the article here quoted.

accompanies the shot. According to Mr. Trauzl,* a grain of black gunpowder (and that, too, in a strong enclosure or envelope) burns off with a speed of only 10 millimetres (0·4 inch) per second, and even the speed of transmission of the flame from grain to grain does not exceed 10 metres (32½ feet) per second. A cartridge about 13 inches long requires therefore 0·03 second for complete ignition, while the individual grains, even when only 1 millimetre (0·04 inch) in diameter, take 0·1 second to attain complete combustion. But with the enormous pressure of the gases due to blasting, tongues of flame of several feet in length may be shot forth within the lapse of 0·1 second, particularly if the shot be "overcharged" or the stemming defective; this development of flame is amply sufficient to cause the ignition of any mass of fire-damp which may be within reach. The coarser grained the gunpowder and the more slowly it burns, the greater is the peril.†

Quite different is the behaviour of so-called "shattering explosives." According to Mr. Trauzl, long charges of compressed gun-cotton or dynamite, exploded at one end by means of a powerful percussion-cap, detonate (even when lying unconfined) with the enormous velocity of 5,500 or 6,500 yards per second, and a dynamite-cartridge 13 inches long takes only 0·0006 second to explode. The lightning-like speed at which the explosion travels, and on which the tremendous blasting effect of these shattering detonators depends, goes far towards limiting, if not entirely excluding, the possibility of the ignition of fire-damp by such means. The incandescence of the decomposing individual particles of the explosive is indeed of such infinitesimally short duration (provided the stemming be good and the detonators sufficiently powerful) that, as a rule, there is no spread of flame likely to occur much beyond the borehole itself.

The above conclusions, based on the theory of the detonation of explosives, as to the difference of behaviour between black gunpowder and the quick-lighting shattering explosives, are found to be in absolute agreement not only with the results of the Neunkirchen experiments (comp. pars. 55 and 76 of this Report), but also with those of the practical experiments carried out by the British Royal Commission on Accidents in Mines‡ and by the Saxon Commission.§ All these experiments unite in proving that the perils of ignition of fire-damp and coal-dust, great as they invariably are when shot-firing is conducted by means of black gunpowder, are reduced to a minimum, or, say, to vanishing point (under ordinary circumstances, and provided no overwhelmingly large accumulations of gas be present) when high explosives are used.

From the point of view of safety, the Prussian Commission consider it, therefore, sufficient to recommend that in fiery mines the use of black gunpowder in blasting operations be entirely dispensed with. On the other hand, they concede the use of shattering explosives so long as the occurrence of fire-damp in a particular locality has not transgressed the bounds of an easily determined "danger-limit." In art. 19 of the "Principles" the recommendations are set forth, as follows:—

* *Technical Aspects of Blasting, Part I.—Fire-damp Question*, by Mr. Ia. Trauzl, Vienna, 1883, pages 10-11.

† The use of so-called "compressed" powder recommended by the French Commission (Mr. Haton de la Goupillière, *Report*, original page 124) reposes on false data. Mr. Trauzl rightly points out that it is this very kind of powder which enhances the risks due to the presence of fire-damp. Moreover, the assertion recently put forward by the representatives of powder-mills, that the danger arising from the use of ordinary or compressed gunpowder is really non-existent if the shots be fired, just as in the case of dynamite, by means of powerful percussion-caps (comp. *Glückauf*, 1885, No. 57) has utterly failed to receive any confirmation in the course of the experiments conducted by the Commission at Neunkirchen.

‡ *Final Report*, pages 36-39.

§ *Jahrb. f. d. Berg-, u. Hüttenwesen im Königreiche Sachsen*, 1886, pages 21-35.

In all fiery mines, it is hereby forbidden to conduct blasting operations which involve the use of black gunpowder or such other slowly-detonating explosives. The use of dynamite, and other quickly-detonating explosives which behave similarly with regard to coal-dust, is alone permissible."

"Even with dynamite, etc., blasting operations are not allowable in those districts (of the mine) where at any working-place under ordinary circumstances such accumlations of fire-damp as are easily recognizable by means of the safety-lamp (3 per cent. of fire-damp) cannot be prevented."

With regard to high explosives, nitro-glycerine compounds have long been known to miners, and have won their way into more or less general use.* According to their composition they may be classed under the several headings of (*a*) Dynamite with a non-effective base, such as kieselguhr-dynamite No. 1; (*b*) dynamite with an effective base, such as cellulose-dynamite, Nobel dynamite No. 2, No. 3, and No. 4, lithofractor, dualine, blasting-gelatine, gelatine-dynamite, and, besides these, we would mention the nitro-cellulose compounds (gun-cotton, etc., Schultze powder, kinetite), and a whole series of new substitutes for nitro-glycerine, such as hellhoffite (Sprengel explosives), carbonite, anagon, securite, roburite, and so on.

Comparing these from the standpoint of their relative degrees of refractoriness (to ignition of fire-damp or coal-dust), the least safe, according to the Neunkirchen experiments appears to be the kieselguhr-dynamite; with this explosive, the "danger-limit" of ignition of gaseous mixtures in presence of coal-dust sometimes oscillated even below 4½ per cent. of fire-damp. It is evident that the non-effective infusorial earth, which is mixed with the nitro-glycerine tends to slacken the speed of propagation of ignition within the dynamite cartridge; it is equally evident that the incandescent particles of infusorial earth, swept forth in the rush of gases resulting from the explosion, tend to heighten the flame-effects of the shot. Wherefore it is easy to understand how, in rocks wherein much gas is occluded, shot-firing by dynamite will ignite the newly liberated gases; and, in fact, this has been repeatedly observed at Obernkirchen and at the Westfalia pit, near Dortmund.† Moreover, the mixing of combustible powder with the nitro-glycerine appears to be detrimental to safety, but only in an appreciable degree when a certain definite proportion is exceeded. And so the unmixed or simple explosives, such as gun-cotton, blasting-gelatine, hellhoffite—nay, even those which are mixed with moderate quantities of powder, such as kinetite, and gelatine-dynamite No. 1 (35 per cent. mixture) were proved by the Neunkirchen experiments to be perfectly safe in gaseous mixtures containing up to 10 per cent. of fire-damp, and in the simultaneous presence of coal-dust. On the other hand, gelatine-dynamite No. 3 (75 per cent. powder-mixture) set fire to mixtures containing as little as 6 per cent. of pit gas.‡

Similar experiments with regard to infusorial-dynamite and gelatine-dynamite were carried out with similar results by the Royal Saxon Board of Mines in the summer of 1885, at Brückenberg No. 1 shaft, near Zwickau.§

A number of more recent experiments, conducted by the Government Inspector of Mines at Neunkirchen, in the Prussian Commission's experimental gallery there and in the König pit, have thrown much light on the behaviour of some of the newly invented high explosives brought forward within the last few years. A

* *The Behaviour and the Management of High Explosives*, Official, Berlin, 1886.

† *Appendices*, vol. i., page 142.

‡ *Appendices*, vol. iv., pages 71-73.

§ *Jahrb. f. d. Berg-, u. Hüttenwesen im Königr. Sachsen*, 1886, page 21, *et seq.*

Schultze powder* of enormous detonating power was shown to be absolutely safe in the presence of fire-damp and coal-dust, while the ordinary varieties of that powder hitherto in use, and the explosive known as anagon† showed no such immunity. The explosive brought forward under the name of securite‡ never seems, indeed to ignite fire-damp or coal-dust even in the most dangerous accumulations; but then, like the Schultze powder, it is hygroscopic, and becomes useless when damp. The same statement holds good of the explosive roburite, made up of a mixture of two substances; moreover, it is not said to be safe when warmed, even to so low a temperature as 30 degs. C. (86 degs. Fahr.). Satisfactory results in every respect—results which have been meanwhile fully confirmed by experiments at other localities, were obtained from carbonite manufactured by Messrs. Schmidt and Bichel of Berlin.§ In saying "satisfactory" we mean both with regard to security against fire-damp and coal-dust, and with regard to its behaviour in actual coal-working in working on a large scale. Considering its remarkable advantages this explosive would appear destined to serve as an efficient substitute for black gunpowder in fiery mines—and this is the more likely, because, even from the point of view of cheapness (low prime cost), carbonite will compete fairly with gunpowder.

91.—*Water-cartridges and Water-stemming.*—The first practical attempt to minimize by means of water-stemming the dangers arising from the flames which accompany blasting-shots appears to have been made by Dr. James Macnab, of London.‖ At the outset, Dr. Macnab had the cartridges enclosed completely in a "shell" filled with water; he then gradually simplified his process (British patent, 1876), bringing the powder-cartridge, provided with a special "igniter," in the ordinary way into the borehole, and clapping immediately on to the ordinary cartridge a water-cartridge. The last-named contained within a *papier-mâché* cylinder two or three times as much water as there was gunpowder in the charge; next to it came the clay-stemming. On the shot being fired, the water was supposed, by "pulverization" and evaporation, to cool the gases arising from the explosion of gunpowder down to a temperature below the ignition-point of fire-damp; also to check flame, sparks, smoke, etc.; and finally, by the prevention of "blowing-out," to greatly strengthen the actual explosive force.** But experiments with the Macnab water-cartridge, carried out both in England and in France,†† very soon

* *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., pages 243-244.

† Compare *Glückauf*, 1885, Nos. 98 and 100.

‡ This would appear to consist in one form of a mixture of dinitro or trinitro-benzene with ammonium nitrate, in another form of a mixture of dinitro or trinitro-naphthalene with ammonium nitrate, and is made from the bye-products of coke and gas manufacture (compare *Iron*, March 4th, 1887, and paper by Mr. S. B. Coxon, of Feb. 12th, 1887, at a meeting of the North of England Institute of Mining and Mechanical Engineers, *Trans.* vol. xxxvi., page 79.

§ Mr. Margraf, "Experiments on the Explosives Hellhoffite and Carbonite," *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., page 59, *et seq.* Recently, the firm of Messrs. Schmidt & Bichel have brought out under the designation of carbonite No. 2, an explosive differing in composition from the original carbonite. The last-named is said to consist of nitro-glycerine, sulphur, benzol, or resin oil, nitro-benzol and infusorial earth, while carbonite No. 2 is made up of saltpetre, carbon bisulphide, a high-boiling product of the distillation of naphtha and a nitrate of the same, also a sulphur containing distillate of [coal-] tar and resin-oil [benzol]. As to the safety of carbonite No. 2 in presence of fire-damp, it certainly shows better results than kieselguhr-dynamite, but it cannot, judging from the experiments, be deemed entirely satisfactory.

‖ Sir Fred. Abel, *Address, loc. cit.*, page 23. Also *Final Report of the British Royal Commission*, page 55. According to Mr. H. Stapenhorst (*Oesterr. Zeitsch. f. Berg-u. Huttenwesen*, 1886, No. 12), the well-known Belgian engineer Mr. Guibal was the first who attempted to cool down, by means of water the gases produced by the explosion of gunpowder; but detailed information in support of that statement is not brought forward.

** Dr. J. Macnab, paper read before the Manchester Geological Society, Nov. 21, 1880 (*Iron and Coal Trades Review*, January 7th, 1887).

†† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, original page 125; *Final Report of the British Royal Commission*, page 55.

demonstrated that, in the case of shots fired with black gunpowder, although the powder smoke does disappear somewhat more rapidly than usual, there is no real security against the ignition of fire-damp by the cartridge, and there is reason to doubt whether the explosive force of the shot is in any way strengthened.

More favourable and striking results with water-stemming were first attained on using shattering explosives, in the course of the labours of the British Royal Commission on Accidents in Mines, under the direction of Sir Frederick Abel.* In 1873, Sir Frederick Abel had already laid down that the effect of a small explosive charge is dispersed over a considerable space by means of the water-column, within which the charge is enclosed. By making use of this principle in connexion with dynamite and similar high explosives, he believed that the shattering effect could be transformed into one more suitable for coal-working—into a tearing [or shearing] effect, like that produced by black gunpowder; and also that the extinction of the flames and sparks arising from the shot could be thereby accomplished. And in fact the first experiments, carried out by Sir F. Abel and Mr. W. Smethurst at the Garswood Hall colliery, near Wigan, in November, 1880, confirmed in the most complete manner the expectations which had been thus formed. Further experiments (conducted by Sir F. Abel and Mr. Galloway, during the years 1881-1886, at Bute Dock and at the Bute-Merthyr and Penygraig collieries in South Wales) have thrown such light on the matter as to enable the method of procedure to be largely developed and much perfected; in some of these cases the water-cartridge completely surrounded the explosive; in others, the former was simply placed upon the latter; and in others, all that was used was a stemming of a spongy character, together with water.

The net result of the experiments made in England may be summarized as follows :—

1. The employment of shattering explosives in conjunction with a water-cartridge offers complete security, even with blown-out shots, against the ignition of fire-damp and coal-dust. Moreover this combination is in coal-working an advantageous substitute for black gunpowder, because the water enfeebles the (merely) local effect of the explosive and helps to ensure a good fall of masses of coal. In hard coal or in rock (stone) half of the length of the borehole must be stemmed in the ordinary way. The water-cartridge may be made up in the simplest and cheapest manner, and gelatine-dynamite may come even into direct contact with the water.†
2. Instead of using an actual water-cartridge, miners may obtain an equal degree of security against explosions of fire-damp and coal-dust by using a porous stemming, saturated through and through with water, say, for instance, wet moss. But the smashing effect of the shattering explosives is not so invariably weakened (toned down) on that system as when a water-cartridge is used. At any rate, gelatine-dynamite is a very good substitute for black gunpowder in coal-working, even when simply used with a porous

* Sir F. Abel, *Address, op. cit.*, pages 23-24; *Final Report of the British Royal Commission*, pages 53-61, 167-186; *Glückauf*, 1885, No. 89.

† In their Final Report (page 60) the British Royal Commission call particular attention to the fact that the water-cartridge for shattering explosives, in its simplest and most efficient form, as described by Sir F. Abel, and published in March, 1881 (*Iron*, March 18th, 1881), is fettered by no restrictions in the shape of patent rights, and may be regarded as public property. The water cartridge announced in October, 1882, by Mr. Miles Settle, and patented for Britain in April, 1883 (compare *Iron and Coal Trades Review*, January 8th, 1886) differs only from that of Sir Frederick Abel by needless and quite unessential additions. The same statement holds good of another water-cartridge, the intention of patenting which has been recently announced; it was experimented with in presence of Mr. Sawyer, H.M. Inspector of Mines, at the Mill Bank colliery, near Newcastle-under-Lyne.

stemming and water. For firing shots in roof or floor or in cross-drifts, any high explosive used with moss and water-stemming leaves nothing to be desired in regard to blasting-efficiency and security against fire-damp.*

3. Black gunpowder and all other slow-burning explosives, whether used with a water-cartridge or with other water-stemming, offer absolutely no security against the ignition of fire-damp and coal-dust.

Only in the summer of 1885 were the Prussian Commission enabled, in the course of their Neunkirchen experiments, to demonstrate unmistakably the unfavourable results obtained from the use of black gunpowder in conjunction with water-stemming.† Similar results were obtained from practical experiments at the Bonifacius and Zollverein collieries near Essen.‡ On the other hand, the experiments conducted by the Royal Saxon mining authorities in September and October, 1885, at the Brückenberg No. 1 shaft, Zwickau, proved, just as those of the British Royal Commission had done, that dynamite and water-stemming offer the most complete security against ignition of fire-damp and coal-dust; and so too it was found impossible to ignite the extremely dangerous coal-dust of the Segen Gottes pit at Brünn, in Moravia (comp. par. 76, arts. 6a and 7 of this Report) by means of dynamite charges with water-stemming.§

92.—*Other Means of Cooling-down or Reducing the Flame which accompanies Shots.*—In order to cool down the gases evolved from gunpowder, immediately after their production, to a point below the ignition-temperature of fire-damp, and thus to render them harmless, Dr. Gurlt‖ suggested shot-firing on the expansion system; this method consists in leaving a hollow space of three times the cubical content of the gunpowder-charge above or below the cartridge. But exhaustive experiments in several collieries of the Saarbrück coal-field have proved the utter inefficacy of such a system, both in regard to security against ignition of fire-damp and in regard to the blasting effect.**

Mr. Bustin†† proposes that on each occasion before a shot is fired, the air in the working-place be so saturated with carbon dioxide (to be led thither from a special reservoir) as to make any explosion of fire-damp impossible: the proportion necessary to bring about such a result, according to Sir H. Davy, is 14 per cent. of CO_2 in an atmosphere of ordinary air. As in such a mixture it is, of course, impossible either to breathe or to keep a light burning, the introduction of the carbon dioxide and the (presumably electric) firing of the shot must be managed from comparatively distant spots; and besides, after the operation, it would be necessary to lead an especially strong air-current up to the working-face. Similarly, Mr. Parent

* In 1886, Mr. W. Galloway took out a patent in Germany (D.R.P. 36847) for a safety-tamping for boreholes. This consists of a spongy mass, saturated with a liquid which is capable of being reduced to a fine spray (compare *Glückauf*, 1886, Nos. 33 and 91; *Zeitsch. Deutsch Ing.*, 1886, No. 44).

† It should be expressly noted here that, even at the time of their final deliberations in June, 1885, the Prussian Commission had as yet no knowledge of the above-mentioned labours of the British Commission, and that it is simply on that account that blasting with water-stemming is not taken into consideration in the "Principles to be Observed in Fiery Mines" (*Appendices*, vol. i., page 67, *et seq.*).

‡ *Glückauf*, 1885, No. 90.

§ *Jahrb. f. d. Berg-, u. Hüttenwesen im Königr. Sachsen*, 1886, pages 34-35; *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1886, No. 1.

‖ *Berggeist*, 1880, No. 101.

** *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 191; Mr. Klose, "Examination of Blasting Materials," *ibid.*, page 97; Mr. Stapenhorst, "Concerning some old Attempts to make Shot-firing in Fiery mines perfectly Safe," *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1886, No. 12: here the attention of the reader is very properly called to the fact that the Gurlt expansion system makes no allowance whatever for the incandescent particles of the explosive which are spurted forth into the surrounding medium.

†† German Imperial Patent, No 17156; *Wochenschrift des Vereines Deutscher Ingenieure*, 1882, No. 12.

suggested* the creation of a "tranquil atmosphere" at the working-face by enfeebling the ventilation, immediately before firing off the blasting-shots, or else, by burning a suitable substance, the creation of a carbon dioxide atmosphere. On the initiative of Sir Frederick Abel, the British Royal Commission on Accidents in Mines† carried out numerous researches with the view of immediately extinguishing the "shot-flame" by means of the addition of a cartridge filled with liquid carbonic acid to the actual blasting-charge. But the results did not always correspond to the expectations which had been formed, partly because the recipient containing carbonic acid did not break (as it should have done) on the explosion of the shot, partly because, even when it did break, a considerable scintillation of sparks ensued [from the shot] despite the carbonic acid thus liberated. Still less favourable were the results attained with cartridges of such substances as decomposed only on explosion of the powder-charge, and should then evolve carbon dioxide; as a matter of fact, they were usually shot forth from the borehole undecomposed.

Moreover, means of mechanically limiting the shot-flame have been over and over again proposed or practically experimented with. Thus Mr. Mallard‡ urged the use of movable doors, which in fore-winning should be brought as near the working-face as possible, and should be closed immediately after the firing of each shot. At the Ida pit, near Hruschau (Austrian Silesia), Mr. J. Böhm§ prevented the ignition of fire-damp, even in mixtures containing as much as 8 per cent. of methane, in cases of strong evolution of the dangerous gases in a cross-drift, or in workings driven to the dip or to the rise, by the following method:—On every occasion before firing off the dynamite charges he shut off the entire working-face by means of a wall (20 to 29 inches thick) of wet sand lined with planks; through this wall only the wires for electric ignition of the shots were allowed to penetrate: its erection entails a very small expenditure of time and money. In the Obernkirchen collieries‖ a successful attempt has been recently made (*i.e.*, in 1885) to absorb, as it were, the tongue of flame proceeding from the blasting-shots by covering up the mouth of the borehole with flat bundles of fir brushwood; it is said that the flame in these experiments did not flash forth beyond the brushwood. In much the same way it has been long sought, in several colliery districts, to render the shot-flame harmless by covering up the borehole with an old wire-gauze.

There remains no doubt that the several methods just discussed, however effective one or other of them may have proved, are on the whole very inferior to the method of water-stemming the shots; and that, from the point of view of safety as well as of simplicity.

3.—*Other Causes of Ignition.*

93.—*Open Furnaces.*—The existence of open fires within the workings of fiery mines, especially conditioned by the putting down the pit of ventilation-furnaces or boiler-installations, may lead to the ignition of such fire-damp as happens to be present. This result is brought about either by the too near approach to the furnace or to the hot products of combustion, even in ordinary conditions of ventilation, of the return air-current saturated with gases, or by a sudden reversal of the draught in extraordinary circumstances. If, therefore, the existence of furnaces below ground be considered at all permissible in fiery mines—a practice which, on

* *Génie Civil des Mines*, August, 1885: *Comptes-rendus de la Soc. de l'Industr. Minérale*, 1885, page 153.

† Sir Fred. Abel, *Address*, *op. cit.*, page 23; *Final Report of British Royal Commission*, pages 53-55.

‡ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 126.

§ Mr. J. Böhm, "Blasting Experiments with Dynamite in the Presence of Fire-damp at the Ida pit, Hruschau," *Oesterr Zeitsch. f. Berg- u. Hüttenwesen*, 1886, No. 17; *id.*, "Blasting in Presence of Fire-damp made Harmless;" *op. cit.*, 1887, No. 13.

‖ *Zeitsch. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., page 245.

the broad grounds of perfect security of ventilation, we should not be inclined to recommend—these furnaces must be provided with such appliances as will exclude the possibility of ignition of the pit-gases by the furnace-gases (compare Art. 4 of the "Principles"). As a matter of fact, however, the statistics of fire-damp explosions in the coal-mines of Prussia from 1861 to the present day (compare par. 30 of this Report) record only a single case—at the Shamrock pit, Herne, Westphalia—wherein ignition of fire-damp was brought about by an open fire (ventilation-furnace).

But, under certain circumstances, furnaces placed at the orifice of the shafts above bank are quite as dangerous as furnaces situated below ground. This statement is peculiarly applicable to the practice formerly in vogue in small pits of arranging ventilation on the so-called fire-kibble system, whereby open "fire-baskets" were suspended in the upcast shaft. Where sudden outbursts of gas in large volume are to be feared, it would seem that even the steam-boiler and other furnace apparatus situated in the neighbourhood of the pit mouth is dangerous; and that this is no groundless fear was shown by the disaster which occurred at the Agrappe pit near Frameries in Belgium on December 17th, 1879. Therefore it is that the Belgian Mines Regulations of April 28th, 1884, state explicitly (sec. 29) that "above bank the necessary measures are to be taken in order to keep distant from any fire the gases which stream forth from the upcast shaft."*

94.—*Fires in the Pit.*—The coal-mining industry of Upper Silesia has had to chronicle in the course of the last thirty years a number of gas-explosions† the directly originating cause of which was fire in the pit. True that, in all these cases, one had only to deal with such gases as were evolved (owing to the pit fire) from the incomplete combustion of the coal (compare par. 62 of this Report). As regards the ignition of ordinary fire-damp by a conflagration in the pit only one case stands so far on record in the annals of Prussian coal-mining. This was at the Neu-Iserlohn pit, Langendreer, Westphalia, in June, 1873; here, however, the real primary cause of the fire-damp explosion was the existence of an underground ventilation-furnace, the furnace by some means setting up a conflagration of the coal-seam.‡ On the other hand, it is by no means a rare occurrence that inversely fire-damp explosions have, for a consequence, conflagrations in the pit; and these in turn, if not soon successfully extinguished, may very easily occasion explosions of gases present or newly evolved in the neighbourhood of the seat of fire.§

95.—*Electric Sparks.*—In presence of the results of the Aix-la-Chapelle experiments (comp. par. 56 of this Report) the electric current also must be set down as one of the sources of danger in fiery mines, immediately the strength of current exceeds 8 ampères. Consequently, the use below ground (in fiery mines) of electric motors or electric transmission of power is only permissible at low-current strengths; otherwise, a mere chance tear or breakage in the conducting-wires would be perilous. And more especially would we deprecate in such mines, even in well-ventilated workings, the use of electric locomotives and similar dynamo-machines, wherein a certain amount of sparking is unavoidable.

96.—*Sparks struck from the Rock in working Hard Stone with Steel Tools.*—

* A similar regulation is suggested in the *Principles to be consulted, etc.*, of the French Fire-damp Commission, sec. 2.

† These are summarized in the *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxx., page 354.

‡ *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., page 154.

§ Prominent examples of this class of disaster are the terrible catastrophes which occurred at the Kronprinz pit, Saarbrück, November 24th, 1868; and at the Wilhelm pit of the Kaiser Ferdinand Northern Railway Company, Poleisch-Ostrau (Austrian Silesia), June 24th, 1884. See Mr. Hilt, *Zeitsch. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xvi., page 148, *et seq.*; and Mr. J. Mayer, *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1885, No. 38 *et. seq.*

It has already been mentioned, by the way, in another portion of this Report (see par. 89) that the steel-mill, which was at one time much in use as a means of illumination, did, as a matter of fact, cause several fire-damp explosions by means of the shower of sparks to which it gives rise. Chief Engineer Joh. Mayer* very properly calls attention to the fact that a similar danger may even arise from the working of hard rocks with steel tools. The experiments which he carried out on this assumption, by means of quick revolution of a disc of hard coal-measure sandstone at whose circumference pointed steel blades were set, proved that ordinary illuminating-gas was ignited in the first few seconds after the disc had been set revolving.† On the other hand, the ignition of natural blower-gas (96 per cent. of methane) could be managed only with great difficulty. If water was made to flow over the scraped or scratched portion of the disc, the evolution of sparks was much enfeebled, and then the ignition of illuminating-gas ensued but seldom; similarly, as the steel blades became blunter and blunter, the shower of sparks became correspondingly smaller and smaller.

Wherefore one may conclude that, although we should not entirely shut out from our minds the possible danger of ignition of fire-damp by sparks from the rock, it is not a risk such as to occasion any special anxiety. The danger would most likely arise in working a very hard siliceous rock, such as coal-measure sandstone or conglomerate. Now, this kind of rock is usually bored through (either with or without blasting, as, *e.g.*, by means of the machine-drill),‡ and in such a case by "boring wet" the sparks are rendered perfectly innocuous.

97.—*Conflagrations arising from Mutual Friction of Hard Rocks at Breaks in the Roof.*—On the basis of the mechanical theory of heat—conversion of work into heat—it may be easily explained how the enormous mechanical work which takes place in worked-out portions of the pit by the subsidence of the roof, and particularly by the sudden, irregular caving-in of large masses of rock, if confined within narrow limits (as, for instance, the area of a pillar) may give rise to very considerable local development of heat.§ Thus it is that Mr. Bernhardi‖ calculates, in the case of the thick coal-seams of Upper Silesia, that a mass of rock 98 feet (30 metres) in thickness caving in with a break of roof would heat a pillar of coal 10 square metres (107·65 square feet) in section, crushed by the break, throughout its whole mass by more than 1,000 degs. C. No wonder, then, that it is often to such irregular breaks of roof that one is accustomed to attribute a large share in the causation of the pit fires frequent in thick seams.

The mutual friction of subsiding strata of rock is often the cause of a really considerable evolution of sparks, a phenomenon to which Mr. Joh. Mayer** first drew attention. This statement is confirmed by a series of remarkable observations from the Ostrau and Rossitz coal-fields in Moravia††, as well as from the Upper Silesian‡‡

* Mr. Joh. Mayer, "Experiments on the Inflammability of Pit Gases by Sparks disengaged from the working of Hard Rocks with Steel Tools, or even from the Friction of such Rocks against one another," *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1882, Nos. 24 and 25.

† Earlier experiments of Messrs. De Villaine and Griot demonstrated that illuminating gas is ignited by the sparks proceeding from an ordinary flint-and-steel lighter (see par. 89 of this Report).

‡ Mr. Habets, *Amsterdam International Exhibition*, 1883, *Documents and Reports by Members of the Jury, Products and Materials for Mines*, 1883, page 58.

§ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 207.

‖ Mr. Bernhardi, "The Heat produced on the Hewing-away of Coal-seams by the resulting Subsidence and Breaking-up of the Rock strata which form the Roof," *Zeitsch. d. Oberschl. Berg- u. Hütten-Vereins*, November, 1886.

** Mr. Joh. Mayer, "Experiments on the Inflammability of Pit Gases, etc." *Oesterr. Zeitsch. f. Berg- u. Hüttenwesen*, 1886, Nos. 24 and 25.

†† Mr. J. Sauer, "Fires Resulting from Caving-in of Rock after Working-out of a Coal-seam." *Oesterr. Zeitsch. f. Berg-u. Hüttenwesen*, 1886, No 29.

‡‡ Mr. Bernhardi, *loc. supra. cit.*

and Westphalian* coal-fields. The sequence of events appears to have been the same in all cases: gradual bending in of the roof, accompanied by ominous crackling; and then suddenly, with a crash like thunder, the masses of rock fall in, and the place is lighted up for several seconds by flaring streams of sparks which together form a veritable "sea of lurid fire." At several of these "cavings-in" the old workings in which they took place were completely filled with explosive pit gases, and yet no explosion ensued.

On the basis of the above observations, Mr. Joh. Mayer extended his experiments, already mentioned in par. No. 96 of this Report, in such wise as to set against his sandstone disc, instead of steel cutters or blades, a check or brake, also made of stone. He then under a pressure of 10 kilogrammes (22 lbs.) made the [whole] arrangement revolve at the rate of 250 to 300 turns per minute. When both disc and check-stone consisted of compact coal-measure sandstone, the consequent sparking was sufficient to ignite illuminating-gas in the course of a few seconds, and the sparks came thickest when the check-stone touched the disc at a few points of contact only. With a sandstone disc and a check-stone of coal-measure shale there was indeed notable incandescence at the points of friction, but the ignition of illuminating-gas was accomplished with great difficulty. Finally, if both disc and check-stone were made of coal-shale, so far from gas being ignited there was not the least appearance of spark or flame. In natural pit-gas, when compact sandstone was used for both disc and check-stone, ignition ensued in every case, but much more tardily than in illuminating-gas, with an interval corresponding to the slower inflammability of the former (compare par. 57 of this Report); still, in some individual cases, the interval was only 10 or 15 seconds.

Although these experiments of Mr. Joh. Mayer can hardly be regarded as exhaustive, they do serve to show this much, when coupled with the actual incipient conflagrations which we have seen occur in old workings; namely, that the sudden crashing-in of the roof of fiery mines, when the rock is very hard [and tough], may well lead to disastrous explosions. There is the possibility even that a number of explosions which have occurred, and whose originating cause has remained so far unexplained, are purely and simply attributable to the sparks struck from the rock by these sudden downfalls. It would appear that the only really effective remedy against accidents of that nature consists in making use of as complete a system of stowing as may be (when working coal) whereby the likelihood of dangerously sudden falls of roof is much diminished, though not entirely excluded.

* Written communications from Mr. Weber, colliery manager at the Hannibal pit, as to observations recorded in that pit and at the Hasenwinkel pit.

(To be continued.)

INDEX TO VOL. IV.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used:—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil, and Mechanical Engineers.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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